CORNELL UNIVERSITY

OFFICIAL PUBLICATION

College of Engineering

THE SCHOOL OF CIVIL ENGINEERING

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

THE SCHOOL OF ELECTRICAL ENGINEERING

THE SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

THE DEPARTMENT OF ENGINEERING PHYSICS

THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

1953–54

Contents

The Approach to an Engineering Career

IT IS important to the young man contemplating an engineering career to recognize that a great many factors will combine to shape his professional progress, and to determine upon the best means, in the relatively short time available to him for his academic preparation, toward the development of the fully rounded background necessary for success. The high degree of technical competence required of the engineer has tended to overshadow the extent to which he is called upon for application of his judgment and integrity to the affairs of the world about him. In fact, the increasing complexity of world affairs and the strong influence of technological progress on economic, social, and political development have brought a high percentage of engineering graduates to positions of leadership in industry, commerce, government, and other areas outside the technical sphere.

It is the responsibility of engineering education, therefore, to develop not only a strong technical background, but to stimulate each engineer toward a broad personal culture as well. It is equally a challenge to each young man preparing for this profession to derive from his collegiate experience all of the elements of practical learning and intellectual inspiration that will foster his growth as an engineer, a citizen, and a leader over the long span of his professional life and in the many directions it may take.

An engineering career has its roots in science and technology, but in its breadth it touches many areas of human activity. The purpose of Cornell engineering and of Cornell life is to create a balanced experience that will serve the engineer in the full range of his future progress. In his studies the Cornell engineer builds a broad foundation of fundamentals in the basic sciences, in basic engineering applications, and in modern technology, much of which is given substance in extensive laboratory practice. He follows a major branch of engineering, avoiding the limitations imposed on future development by narrow specialization—in fact, he studies fundamentals in the adjacent areas of engineering in

anticipation of a wide scope of future activities. This broad basic approach has enabled a considerable number of Cornell engineers to develop opportunities outside their original fields of study and experience and to gain distinction in complex enterprises requiring the coordination of many and varied activities.

The further development of this kind of background is supported by the inclusion of a solid core of liberal, general, and managerial studies throughout the period of his technical studies. By including the equivalent of a full year's work in these studies in the five years of engineering training, the young engineer achieves a broadened philosophy and understanding as a natural part of his professional background.

Formal academic work occupies a substantial part of each student's time; nevertheless, it is only a part. Beyond this are the opportunities of university life that form a distinctive influence in personal development and that should be a primary objective in the plan of each student for a collegiate experience of maximum effectiveness. We are particularly happy that the Cornell engineer can study and live in an atmosphere that is not only of strong engineering aspect but that is charged as well with the vitality of a university community dedicated to scholarship in the whole range of human endeavor. He carries with him, therefore, not only the components of his own learning, but also the intellectual stimulation of his association with the university community and the spiritual influence of the university's natural setting. Much of the Cornell tradition has been shaped of these factors; much of the purpose of Cornell engineering gains substance through their effect.

It is our aim to make available to the students who have shown the aptitude, character, and high determination for engineering study at Cornell all of the elements of knowledge, experience, and inspiration that will make for notable achievement in a long professional career.

S. C. HOLLISTER
Dean

The College of Engineering

ITS HISTORY AND ORGANIZATION

ENGINEERING has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to . . . the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs, who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator, who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. The first was originally called the College of Mechanic Arts and later the Sibley College of Mechanical Engineering and Mechanic Arts, in recognition of munificent gifts by Hiram Sibley, founder of the Western Union Telegraph Company, and his son, Hiram W. Sibley. Civil engineering, originally a separate school in the College of Mathematics and Engineering, and later the College of Civil Engineering, has also retained its identity to the present day.

In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established as one of the three component units, on a par with the Sibley School of Mechanical Engineering and the School of Civil Engineering. In 1946 the Graduate School of Aeronautical Engineering was established. Also in 1946 the Department of Engineering Physics was organized with a five-year curriculum leading to the degree of Bachelor of Engineering Physics. All undergraduate cur-

ricula have now been extended to five years in order to provide the necessary technical preparation and at the same time to include the very desirable training in nontechnical subjects.

The College of Engineering organized courses in chemical engineering in 1931; and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of Bachelor of Chemical Engineering. A course in metallurgical engineering has now been added, and the name of the school has been changed to the School of Chemical and Metallurgical Engineering.

Students in engineering use the several buildings which house the Sibley School of Mechanical Engineering and, in addition, Lincoln Hall, devoted to the School of Civil Engineering; Franklin Hall, containing most of the School of Electrical Engineering; Rand Hall, the gift of Mrs. Florence O. R. Lang, housing electrical laboratories; the Hydraulic Laboratory on Beebe Lake above Triphammer Falls; and Olin Hall of Chemical Engineering, which was given by Franklin W. Olin to provide for the School of Chemical and Metallurgical Engineering. In 1952 a new building for materials laboratories was dedicated. One section, for research and instruction in materials, is named Thurston Hall, after Robert H. Thurston, first director of Sibley and organizer of the first collegiate laboratory of materials. The other laboratory, for materials processing, bears the name Kimball Hall, after Dexter S. Kimball, former dean of the College of Engineering and pioneer of courses in industrial engineering. For various preparatory and elective courses students also use the Baker Laboratory of Chemistry, given to the University in 1922 by George F. Baker, and Rockefeller Hall, erected by John D. Rockefeller for the Department of Physics, as well as other buildings of the College of Arts and Sciences.

Cornell engineers enjoy all the benefits and privileges of an outstanding university community. They associate continually, in fraternities and dormitories, in extracurricular activities, and in general University functions, with students of liberal arts, agriculture, law, veterinary medicine, architecture, and other subjects. Concerts by world-famous soloists and orchestras, lectures by renowned scholars in widely varying fields, dramatic productions, and art exhibits add to the cultural atmosphere in which Cornell engineers live as undergraduates.

These facts, in addition to the beauty of the campus and the surrounding Finger Lakes region and the consideration that Ithaca is a small city, removed from the distractions of a metropolitan area but easily accessible by railroad and highway, help to explain the composition of the student population, which each year includes students from every part of the United States and numerous foreign countries.

The College of Engineering now comprises the School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engi-

neering, the Department of Engineering Physics, the Departments of Mechanics and Materials, and the Graduate School of Aeronautical Engineering. Graduate instruction in engineering is offered by the Engineering Division of the Graduate School of the University.

OBJECTIVES OF CORNELL ENGINEERING

The broad purpose of instruction—and of the many phases of student life at Cornell—is to provide the elements of learning and inspiration that foster leadership in professional and personal affairs. In the record of achievement of generations of Cornell engineers, the University has a trust to maintain a high standard of academic experience and to select those students whose abilities, character, and purpose show promise of continuing a tradition of leadership.

Since the engineer has need of a balanced background, combining strength in fundamental technical knowledge with broad understanding of human affairs and competence in human relations, the Cornell plan provides for full integration in a single five-year period of both areas of study. It holds to two major principles: (a) that preparation for the uncharted technological advances of the future can come only from a solid foundation in the fundamentals of science and engineering, and (b) that the total collegiate experience of the engineering student should be a stimulus to lifelong intellectual growth rather than a "package" of incidental knowledge.

In conformance with these principles, the Cornell program is shaped of four integral stems of learning: (1) basic science (mathematics, physics, chemistry); (2) applied engineering science (mechanics, properties of materials, thermodynamics, electrical theory, and similar subjects); (3) applied technology (structural design, hydraulics, machine design, industrial engineering, electronics, power, chemical operations, and many other subjects related to modern engineering practice); (4) general, managerial, and liberal studies (English, history, management, psychology, public speaking, economics, law, and such additional subjects in the several divisions of the University as the student may elect to pursue for well-rounded personal development).

Upon the foundation of basic science and applied engineering science is built the understanding of technological processes and the ability to derive new applications from fundamentals—an ability essential to future development.

In the applied technology stem, students follow the engineering applications pertaining to their major branch of engineering. Although modern practice, laboratory experience, and practical methods are followed, studies again are related to the basic principles involved in the applications so that the student will gain an instinct for creative development from fundamental facts.

The stem of general, managerial, and liberal studies occupies a minimum of 20 per cent of each student's program. Some of these studies are prescribed, and some can be elected, with the objective of expanding personal interests and abilities. These studies are carried throughout the full period of the student's attendance so that, combined with his experiences and associations in a university community of broad interests and activities, they form an integral and natural part of his personal culture and a stimulus to further intellectual development.

No small part of the Cornell engineer's cultural background comes from his living in a setting of inspirational natural beauty, in close association with students and scholars from all parts of the world with all ranges of interest—agriculture and the arts, medicine and law, history and social science, as well as the physical sciences and technology.

The Cornell program includes both the more intensive technical training and the core of liberal experience essential to the long-range requirements of a full professional career. Its design avoids the necessity for narrow specialization, or for restriction of basic areas of study, and provides instead for a balanced background leading to broad technical competence, to a comprehension of the economic, social, and political forces with which engineers must deal, and to competence in the techniques of management and human relations.

Each entering undergraduate student selects the division of major study he expects to follow (chemical, civil, electrical, mechanical, metallurgical engineering, engineering physics). Aeronautical engineering can be followed as a graduate program upon completion of any of the undergraduate engineering programs or of a satisfactory major program in mathematics or physics. Similarly, graduate study in the respective areas of engineering can be undertaken by qualified students who show aptitude for advanced study in their undergraduate careers.

Since a primary purpose of Cornell engineering is to build a broad base of fundamentals, all engineering students study common basic subjects for a substantial part of the first five terms. This has the incidental advantage of permitting some transfer to adjacent major areas after original enrollment without serious loss of time, but it is primarily intended to prepare Cornell engineers for the diverse channels of engineering practice and for the many areas in which the activities of specific fields overlap.

Both in basic studies and in the study of technical processes and applications, laboratory practice, large-scale demonstrations, and field experience are used extensively. Students are expected to acquire considerable aptitude in integrating their various studies and experiences for the solution of practical engineering problems in their later courses.

The College is engaged in an extensive program of engineering research which is being carried out by members of the Faculty and their assistants. Although most of these projects are not directly associated

with undergraduate activities, they create a stimulating atmosphere for academic work and provide a firsthand opportunity for all students to observe the ingenious application of basic principles to the extension of engineering frontiers.

In all, the objectives of Cornell engineering are achieved through the mutual determination of the student and the College to develop in the five-year period of his academic life the technical background and the personal culture that will support continuing growth over the full span of his professional career.

THE INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term of the regular curriculum students in electrical and mechanical engineering who are in good standing may apply for admission to the Industrial Cooperative Program.

The Cooperative Program provides three work periods of term length (about 16 weeks each) in one of the following industries operating the plan with the University: American Gas and Electric Service Corporation, Air Reduction Company, General Electric Company, Philco Corporation, and Procter and Gamble.

By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all the academic work regularly required for the Bachelor's degree and can graduate with their regular classes. The schedule is as follows after Term 4:

Period	*Term*	*Term*	*Term*
Summer	5	Industry	8
Fall	Industry	7	9
Spring	6	Industry	10

It is to be noted that the Cooperative student remains with his regular classmates during all terms on campus except the fifth and eighth, which he takes in the summer. The Cooperative Program therefore is not an accelerated program and involves a minimum of departure from the regular program.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and provides an invaluable opportunity for him to direct his study interests on campus toward the realities of his future environment. Supervision is provided for each student, both from campus and industry, to ensure his obtaining optimum benefit from the Program. Many students have found this a profound influence on their objectives and on their progress both before and after graduation.

Applications for the Cooperative Program are accepted in the fourth term only. Applicants are subject to approval both by the College and by

one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

CHOICE OF CURRICULUM

Every applicant for admission is asked to designate the branch of engineering he wishes to study, namely, civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgical engineering, or engineering physics. Each branch has its own curriculum which carries its own professional degree.

The first year of study is essentially the same for all branches and includes mathematics, physics, chemistry, English, and appropriate courses in descriptive geometry or drafting. This similarity of the curricula in the freshman year makes it possible for students to transfer from one division to another of the College without great hindrance when for one reason or another a change of objective is desirable. Thus, no applicant in his first year need feel that by committing himself to a particular branch of engineering education he has made an irrevocable decision.

After the second year, as the several curricula begin to diversify, transfer within the College of Engineering is somewhat more difficult and in a few instances may necessitate an additional term or more of study.

Applications for transfer should be made to the Director of the prospective school during the term preceding the one in which the student wishes to change his course, and students should realize that the earlier such transfers are made the fewer will be the resulting complications of curricular adjustment.

DEGREES OFFERED

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechanical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Ch.E.); Bachelor of Metallurgical Engineering (B.Met.E.); and Bachelor of Engineering Physics (B.Eng. Phys.).

The advanced degrees of Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) are granted by the University on the recommendation of the Faculty of the Graduate School.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the Faculty of the Graduate School of Aeronautical Engineering.

REQUIREMENTS FOR GRADUATION

Baccalaureate degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in military science and tactics and physical training and in the payment of tuition and fees.

2. He must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that Faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

Requirements Changeable

The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded, and such changes are applicable to either prospective or matriculated students at any such time as the college may determine.

UNIVERSITY REQUIREMENTS

MILITARY TRAINING . . . All physically qualified undergraduate men who are American citizens must take military training during their first four terms. Enrollment in the basic course of military science and tactics or air science and tactics, or in the first two years of naval science, satisfies this requirement. Students transferring to Cornell from other institutions are exempt from part or all of the requirement, according to the number of terms of residence in college before transfer, and service in the armed forces in World War II also satisfies the military training obligation. Entering students who have had ROTC training in secondary or military schools are requested to bring WD AGO Form 131—Student's Record for presentation to the Military Department at the time of registration (see also page 117 of this Announcement).

PHYSICAL TRAINING . . . All undergraduate students must pursue four terms of work, three hours a week, in physical training. Ordinarily, this requirement must be completed in the first two years of residence; postponements are to be allowed only by consent of the University Faculty Committee on Requirements for Graduation.

Exemption from this requirement may be made by the committee designated above, when it is recommended by the medical office or when unusual conditions of age, residence, or outside responsibilities require it.

For students entering with advanced standing, the number of terms of physical training required is to be reduced by the number of terms which the student has satisfactorily completed (whether or not physical training was included in his program) in a college of recognized standing.

GRADUATE STUDIES

A graduate of this college or of other colleges of engineering may enter the Graduate School of Cornell University and pursue advanced work in engineering. Such a student may enter either as a candidate for a degree (M.S. or Ph.D.) or without candidacy for a degree, according to the character of his previous training. A prospective graduate student should consult the *Announcement of the Graduate School* and apply to the Dean of the Graduate School. Information concerning graduate scholarships and fellowships, including the John McMullen Graduate Scholarships, can be obtained either from the Dean of the Graduate School or from the Dean of the College of Engineering.

Prospective candidates for the degree M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

ENGINEERING LIBRARY

This library maintains working collections in the fields which it serves. Each year the most important new books are added to its stacks, as well as current issues of engineering journals, and transactions and proceedings of many learned societies.

The library of the Schools of Civil, Mechanical, and Electrical Engineering in Sibley Dome includes, in addition to the regular collection, the following collections and facilities: The Kuichling Memorial Library and the support of the Irving Porter Church Fund in Civil Engineering; the Diederichs Memorial Library in Mechanical and Electrical Engineering and the James F. Lincoln Arc Welding Foundation Library in Mechanical Engineering; and the Alexander Gray Memorial Library in Electrical Engineering.

The School of Chemical and Metallurgical Engineering in Olin Hall has the facilities of an unusually complete library in chemistry, chemical engineering, and metallurgical engineering.

A complete library of collections in physics and applied physics with large reading rooms is maintained in Rockefeller Hall as the Physics Branch of the University Library.

STUDENT PERSONNEL SERVICES

STUDENT PERSONNEL OFFICE . . . The admission of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any questions relating to their life in the College.

STUDENT COUNSELING . . . In general, the counseling of students rests with the Class Advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work. In each School of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the Dean, Directors, department heads, and instructors not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and Dean of Women and their staffs may be consulted by students regarding their nonacademic problems. Both Deans have offices in Edmund Ezra Day Hall.

ASSISTANCE TO FOREIGN STUDENTS . . . The University maintains on its staff a Counselor to Foreign Students, whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office is in Edmund Ezra Day Hall. It is suggested that all foreign students write him before coming to Ithaca or call on him immediately upon arrival. He will be glad to help them find suitable living quarters, either at the Cosmopolitan Club or elsewhere, and introduce them to other University officials, members of the Faculty, and other students.

FRESHMAN ORIENTATION . . . A series of orientation lectures is given to students in the fall term of the freshman year in the College of Engineering. The primary purpose of these lectures is to acquaint the student with the scope of each of the major fields of engineering and with the opportunities and the responsibilities of men in the engineering professions.

THE ENGINEERING COLLEGE COUNCIL

The Engineering College Council consists of the President of the University, the Dean of the College, and a group of distinguished engineers, usually alumni, approved by the Board of Trustees of the University. The duties of the Council are to become thoroughly acquainted with the affairs of the College, to advise the administration and the Board of

Trustees with regard to policies and programs designed to increase the efficiency of the established operations, to add to the available resources, to improve public and alumni relations, and in any other way to strengthen the College's work.

MISCELLANEOUS INFORMATION

DEAN'S HONOR LIST . . . Students of the College of Engineering whose weighted average in their studies is 85 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the college.

STUDENT ACTIVITIES . . . Students of the College of Engineering find many opportunities for engaging in wholesome activities outside their regular duties, and even outside the College, in company with other members of the University community. Within the College some find congenial occupation in helping to carry on the student branches of the national engineering societies, in conducting *The Cornell Engineer,* or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts—musical, dramatic, journalistic, social, and athletic.

ENGINEERING SOCIETIES . . . The College of Engineering is closely associated with the local sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Automotive Engineers, and Institute of Radio Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of Aeronautical Sciences. The Cornell Metallurgical Society was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers. Students in the Department of Engineering Physics formed in 1948 the Cornell Society of Engineering Physics. The meetings of such societies afford opportunities for addresses by engineers of eminence, for the presentation of papers by students, for discussion, or for contests in public speaking on engineering subjects. The School of Mechanical Engineering gives elective credit hours for activity in the student branches of the A.S.M.E.

The Cornell Engineer, a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering.

ADMISSION

METHOD OF APPLICATION AND REQUIREMENTS FOR ADMISSION . . . All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission and methods of procedure are outlined in the University's *General Information* booklet, which every candidate for admission should read carefully and which can be obtained by application to Cornell University Official Publication, 343 Edmund Ezra Day Hall, Ithaca.

Entrance subjects must include English (four units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) *or* history (two units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of sixteen be in language or history. Applicants are also advised to offer advanced algebra rather than solid geometry, when a choice is possible. Candidates for admission to the School of Chemical and Metallurgical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Test of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell University. Candidates are urged to take the tests in January of their senior year.

SELECTIVE ADMISSION . . . The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The committees on admissions in each of the Schools will exercise discretionary power in selecting those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the admission committee to give thorough consideration to their qualifications.

PAYMENTS TO THE UNIVERSITY

TUITION AND OTHER FEES . . . For information concerning tuition and other fees payable to the University, see the *General Information* booklet.

HEALTH SERVICES AND MEDICAL CARE

These services are centered in the University Clinic or out-patient department and in the Cornell Infirmary or hospital. Students are entitled to unlimited visits at the Clinic; laboratory and X-ray examinations indicated for diagnosis and treatment; hospitalization in the Infirmary with medical care for a maximum of 14 days each term; and emergency surgical care. The cost for these services is included in the College and University general fee. For further details, including charges for special services, see the *General Information* booklet.

FINANCIAL AID

Scholarships

General awards, open to entering students in *any* undergraduate division of the University, are described in the Announcement entitled *Scholarships and Grants-in-Aid*. They include the Cornell National Scholarships, the LeFevre Scholarships, and the University Tuition-Aid Scholarships. The scholarships described below are available *only* to students entering the College of Engineering.

Application blanks for all freshman scholarships may be obtained directly from the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall.

John McMullen Regional Scholarships are awarded annually to thirty or more selected students entering the College of Engineering. These scholarships are awarded primarily to male students whose preparatory work has been completed in schools outside New York State; a small number are awarded to entering students from New York schools. These scholarships have variable stipends up to $350 a term and may be held throughout an undergraduate course of study, provided the recipient maintains the required academic record. They were established by the Board of Trustees from a portion of the income of a munificent gift to the University by the late John McMullen of Norwalk, Connecticut, and are allotted among sixteen districts of the United States. Applications are to be returned to the Scholarship Secretary before March 1. The candidates selected for final consideration are requested to take the Scholastic Aptitude Test of the College Entrance Examination Board in January. These candidates are also interviewed by members of an alumni scholarship committee in their respective districts. Final selections are based upon the secondary school record, the aptitude test, and qualities of character and general ability.

John McMullen Industrial Scholarships in Engineering are awarded each year to four graduates of secondary schools who have spent some time in industry and have had apprentice training, preferably in a formal

course given by an industrial concern. Candidates must be sponsored by responsible officers of the companies by which they have been employed. Each scholarship has a value of $350 a term and may be held throughout an undergraduate course of study provided the recipient maintains the required academic record. Inquiries should be addressed to the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall, not later than February, so that formal applications may be filed before March 1.

The Edward P. Burrell Scholarships in engineering with stipends up to $400 a year are awarded annually, to freshmen only, on the basis of scholastic background and financial need.

Grants and Other Aid

Students who establish superior academic records become eligible for John McMullen Regional Scholarships after one term of residence, regardless of the state in which they reside. Other scholarships, grants, and loans open to undergraduates are reserved for students who have been in residence and good standing at Cornell University for at least two terms.

Any student in the College of Engineering who needs financial aid should immediately consult the Director of his School. Ordinarily a single application is sufficient to assure consideration for all available scholarships and grants. When this is not true, the Director will instruct the student as to the proper procedure for making application. Scholarship applications for the following year received before April 1 will be given primary consideration. Late applications can be considered only for vacancies.

Certain grants are drawn from the income of special funds, the gifts of persons who in many instances have specified to whom in general their benefits are to apply. They are not as a rule available for aid to freshmen.

Much of the financial aid which the University is able to give undergraduate students is in the form of loans from the income of endowments which are administered for the Trustees by the standing Committee on Student Aid, of which the Dean of Men is chairman. The benefits of these funds are reserved for students who have been in residence and in good standing at Cornell University for at least two terms, and preference is given to applicants of high scholastic standing who are within a year of graduation.

A special fund from which loans may be made to students in the School of Chemical and Metallurgical Engineering has been created by contributions from graduates of that School.

Students in the Graduate School of Aeronautical Engineering, as well as other graduate students whose major subjects are in the various branches of engineering, are eligible for the John McMullen Graduate Scholarships. There are also a number of fellowships established by the Cornell Aeronautical Laboratory, Inc., in honor of its affiliated companies; these are awarded in various branches of engineering and science.

For information on other awards available to graduate students in engineering reference should be made to the current *Announcement of the Graduate School.* Candidates for the degree M.Aero.E. should make application for these awards by writing directly to the Director of the Graduate School of Aeronautical Engineering. Candidates for other graduate degrees, including the Ph.D. in any field, must apply to the Dean of the Graduate School.

Prizes

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by students of the University generally. A list of them, under the title *Prize Competitions,* will be mailed on request addressed to Cornell University Official Publication, 343 Edmund Ezra Day Hall. Other prizes are open to competition particularly by students of the College of Engineering, as follows:

The Fuertes Medals, established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the Faculty to that student of the School of Civil Engineering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at least two years. The other is awarded annually by the Faculty to a graduate of the School of Civil Engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the Faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

The Fuertes Memorial Prize in Public Speaking, founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $100, one of $40, and one of $20, are offered annually to all students of the Colleges of Engineering and Architecture who are in the fifth term or beyond, for proficiency in public speaking.

The Charles Lee Crandall Prizes, founded in 1916 by alumni of the School of Civil Engineering: prizes of $75, $50, $35, and $20. They are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by seniors or juniors in that School on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate

interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before May 1 of each year.

Sibley Prizes. Under a gift of Hiram Sibley, made in 1884, the sum of $100 is awarded anually in several prizes to fifth year students in Mechanical Engineering and Electrical Engineering, equally distributed, who have received the highest average in the preceding four years.

The J. G. White Prize in Spanish. Through the generosity of James Gilbert White (Ph.D., Cornell, '85) three prizes, established in 1914, each of the value of $100, are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

The Robert Harris Simpson Prize, founded in 1933 by Mrs. Simpson in memory of her late husband, Robert Harris Simpson, C.E. '96. This prize of $25 is awarded annually to that senior in the School of Civil Engineering who submits the best technical description or design of a civic improvement of sufficient substance and merit to justify the award. Papers or designs must be submitted on or before December 15 of each year and are judged by a committee appointed by the Director of the School of Civil Engineering.

The Institute of Aeronautical Sciences Prize. The "Student Branch Scholastic Award" of the Institute of Aeronautical Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

The Wunsch Cash Prizes will be awarded annually to students for the best papers on "Materials Handling." Awards will be made from the income of a permanent fund known as the "Silent Hoist & Crane Company Materials Handling Prize Endowment."

Faculty and Staff

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School of Civil Engineering

EQUIPMENT

THE PRINCIPAL building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, and laboratories.

The laboratories in Lincoln Hall include the testing laboratory, equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by civil engineers; and the sanitary laboratory, with facilities for physical, chemical, bacteriological analyses of water and sewage and for research in the field of sanitary engineering.

The soil mechanics laboratory is located in a separate building and has available facilities for instruction, standard laboratory work, and specialized research in this field.

The highway laboratories are housed in separate buildings and are equipped for making the standard tests and for research in the field of highway engineering. Astronomical equipment in the Fuertes Observatory includes the instruments required for determining time, latitude, longitude, and azimuth.

A hydraulic laboratory, situated at the outlet of Beebe Lake, is under the jurisdiction of this School. In addition to student instruction and research, this laboratory provides facilities for hydraulic investigations carried on in cooperation with governmental agencies and private companies.

COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering. The courses are all planned to provide fundamental instruction for the practice of the profession. To meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various fields which can be planned to intensify his training in a specific area or to increase his general background.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to impart knowledge of the fundamental principles of design, construction, and operation of

structures and works of the civil engineering type, in addition to providing a liberal opportunity for study of general and cultural subjects. Emphasis is placed upon civil engineering as an applied science rather than as a vocational technique.

Civil engineering students follow the first year with as thorough a preparation as possible in the following subjects: the survey, design, construction, and operation of buildings, roads, railroads, canals, sewers, and water works; the construction of foundations under water and on land, and of superstructures and tunnels; the survey, improvement, and protection of coasts, and the regulation of rivers, harbors, and lakes; the astronomical determination of geographical coordinates for geodetic and other purposes; the application of mechanics, graphical statics, and descriptive geometry to the construction of the various kinds of arches, girders, roofs, trusses, suspension and cantilever bridges; the drainage of districts, sewerage of towns, and irrigation and reclaiming of land; the applications and tests of hydraulic and electric motors; the preparation of drawings, plans, specifications, and the proper inspection and tests of the materials used in construction. Instruction is given in engineering economy, finance, and jurisprudence. The latter subject deals chiefly with the fundamental principles of the law of contracts. Opportunity is also given to seniors to specialize to a limited extent or to broaden their training by the election of certain courses, some of which may be chosen from approved courses in any department of the University.

The instruction in mathematics, chemistry, physics, geology, economics, and English is given in the College of Arts and Sciences. All other regular subjects are taught in the School of Civil Engineering, the School of Mechanical Engineering, or the School of Electrical Engineering. Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

SCHOLASTIC REQUIREMENTS

A student in the School of Civil Engineering who does not receive a passing grade in every course in which he is registered or fails in any term or summer session to maintain a minimum average of 70 per cent may be placed on probation or dropped from the University.

CURRICULUM (B.C.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Total	15		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	3	2½
	English 112, Introductory Course	3	3	0
	Engineering 2002, Drawing	3	1	6
	Engineering 2111, Elementary Surveying	2	0	5
	Total	17		

In addition to these courses, all freshmen must satisfy the University's requirements in military science and tactics and physical training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry or Chemistry 402, Physical Chemistry	2	2	0
	Geology 113, Engineering Geology (or Economics 107)	3	2	5
	Engineering 2112, Advanced Surveying	3	2	2½
	Engineering 1151, Mechanics-Statics	3	3	0
	Total	17		
TERM 4	Physics 118, Physical Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry or Chemistry 301, Organic Chemistry	2	2	0
	Economics 107, Introduction to Economics or Geology 113	3	3	0
	Engineering 2113, Route and Aerial Surveying	3	1	5
	Engineering 1152, Mechanics-Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Total	17		

In addition to these courses, all sophomores must satisfy the University's requirements in military science and tactics and physical training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Engineering 2103, Summer Survey Camp	5	—	—
	Engineering 1134, Strength of Materials	3	—	—
	Engineering 1211, Materials (or 2901)	3	2	2½
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 2501, Microbiology in Engineering (or 2725)	3	2	2½
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 2602, Transportation (or Accounting 3231)	3	3	0
	Total	18		
TERM 6	Engineering 2901, Construction Methods (or Materials 1211)	3	3	0
	Engineering 2302, Hydraulics	3	2	2½
	Engineering 3231, Accounting (or 2602)	3	2	2½
	Engineering 2702, Elements of Metal and Timber Structures	3	0	7½
	Engineering 1145, Applied Mathematics	3	3	0
	Engineering 2725, Soil Mechanics (or 2501)	3	2	2½
	Total	18		
TERM 7	Engineering 1212, Materials Laboratory (or 2412)	3	1	5
	Engineering 2704, Statically Indeterminate Structures (or Speech 101)	3	3	0
	Engineering 2502, Water Supply and Treatment (or 2503)	3	2	2½
	Engineering 2715, Reinforced Concrete Design (or 2610)	3	1	4
	Engineering 2902, Engineering Law (or 2903)	3	3	0
	Engineering Economics 203, Money, Currency, and Banking	3	3	0
	Total	18		
TERM 8	Engineering 2412, Hydraulics (or Materials 1212)	3	3	0
	Engineering 2503, Sewerage and Sewage Treatment (or 2502)	3	2	2½
	Engineering 2720, Foundations (or 2904)	3	2	2½
	Engineering 2610, Highway Engineering (or 2715)	3	2	2½
	Engineering 2903, Economics of Engineering (or 2902)	3	3	0
	Public Speaking 101 (or 2704)	3	3	0
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 9	History 165, Science in Western Civilization	3	3	0
	Engineering 2713, Structural Design (or 2720)	3	2	2½
	Engineering 3541, Heat Power I	3	2	2
	Engineering 4931, Electrical Engineering	3	2	3
	Electives (Free)	6		
	Total	18		
TERM 10	Engineering 3542, Heat Power II	2	2	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 2904, Public Administration (or 2713)	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Industrial and Labor Relations 293, Survey of Industrial and Labor Relations	3	3	0
	Electives (Free)	6		
	Total	20		

Grand total for ten terms: 181 credit hours including summer survey camp, but not including military science and tactics or physical training.

Sibley School of Mechanical Engineering

EQUIPMENT

THE SIBLEY SCHOOL of Mechanical Engineering, named in recognition of important gifts made by Hiram Sibley and his son, Hiram W. Sibley, occupies a group of buildings at the north end of the campus. In addition to the Sibley buildings, the new Kimball Hall, housing all equipment related to materials processing, is now available at the south end of the campus adjacent to the new Thurston Hall for engineering mechanics and materials testing. The school is provided with a central working library in Sibley Dome, and many of the departments also maintain special working and reference libraries.

Numerous laboratories and shops are available for carrying on the many activities of the School of Mechanical Engineering, as follows: the materials testing laboratory, heat treatment laboratory, and metallography laboratory, for determination of the physical properties of engineering materials under various conditions; the machine design laboratory, for instruction and research in photoelasticity, balancing, vibration, stress, lubrication, and wear of machines and machine members; the steam laboratory, for instruction and research involving steam power; the internal-combustion engine laboratory, for work with this type of power equipment; the M.E. hydraulics laboratory, a pump-operated laboratory for hydraulic problems; the lubrication laboratory, for determination of the physical properties of lubricants; the refrigeration laboratory, for the study of refrigeration; the fuel testing laboratory, for determination of the composition and calorific value of all types of fuel; the micromotion laboratory, for motion and time study; the constant-temperature room, and the heat transfer, heating, ventilating, air conditioning laboratories; a series of research laboratories; the materials processing laboratories—the woodworking and pattern shop, the machine shop and gage laboratory; the laboratory boiler house; and the University heating plant and power house.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and provide

as much training in engineering practice in the fields of mechanical engineering and engineering administration as can well be imparted in a school.

Students of mechanical engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition the mechanical engineer may engage in scientific research in the innumerable branches of this field.

During the earlier terms, fundamental instruction is given in mathematics, physics, chemistry, drawing, materials processing, mechanics of engineering, strength of materials, materials of construction, mechanism, applied mathematics, economics, industrial organization and management, English, public speaking, and psychology. This fundamental training is followed during the last three years with instruction in the fields of thermodynamics, heat transfer, fluid mechanics, machine design, cost control, electrical engineering, testing of materials, steam power-plant engineering, combustion engineering, refrigeration and air conditioning, mechanical engineering, laboratory practice, advanced mechanics and strength of materials, advanced work in materials processing, industrial history, business law, and industrial engineering.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

Project and Electives

During the last two years, provision is made for the choice of elective courses and a senior project in the student's major field of study. His project may be an individual one or a group project in a technical, managerial, or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing the ability to do work of an original nature.

The project may be in any one of many branches, such as management, industrial engineering, heat-power engineering, internal combustion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, experimental stress analysis, design development, advanced mechanics and strength of materials, engineering materials, experimental engineering, materials processing, tool engineering, welding design, structural engineering, physics, electrical engineering, and other fields related to mechanical engineering.

Options

The curriculum in mechanical engineering is common for all students during the first four terms. During the fourth term a selection of either Option A or Option B must be made by the student, which choice determines the curriculum and time available for electives for the balance of his undergraduate study. Both choices lead to the B.M.E. degree. The Option A curriculum has been designed to satisfy the needs of those students desiring specialization within some one field of mechanical engineering. This option requires somewhat more work in the fields of heat-power engineering and electrical engineering but also provides for more free elective hours than does Option B. The Option B curriculum is designed to satisfy the needs of students intent on entering the manufacturing and industrial phases of engineering work. Much of the course work is given by the Department of Industrial and Engineering Administration. The scope of this work is indicated by the courses described on pages 42-43. The choice of this option prepares the student to enter into any of the many phases of engineering associated with manufacturing as described below.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Many prospective students are interested in careers where an excellent technical training will be of benefit but where the problems faced are essentially due to combinations of managerial, human, and technical factors. The Option B Curriculum, designed to replace the Administrative Engineering program formerly offered at Cornell, provides a balance of basic sciences, technical engineering, and managerial course requirements which, when combined with the liberal courses and electives in the five-year curriculum, result in excellent training for a career in modern industry. The increasing scientific developments underlying the operation of works and plants in many industries render the type of training provided in Option B an essential prerequisite to further training in industry for managerial positions. The incorporation in the curriculum of training in the fundamentals and procedures of industrial management has a history of over fifty years at Cornell in the Sibley School of Mechanical Engineering.

It is possible for superior students to plan their work so that they may register in both the College of Engineering and the School of Business and Public Administration in the fifth year. Thus requirements for the degree of Master of Business Administration may be completed in the sixth year of residence.

The existence of a School of Industrial and Labor Relations, a College of Arts and Sciences, and other divisions of the University on the same campus as the College of Engineering makes possible combinations of elective courses available at few technical schools in the country.

Preparation for Aeronautical Engineering

Option A is especially recommended by the Faculty of the Graduate School of Aeronautical Engineering as preparation for study in that School. Ordinarily, the program leading to the degree M.Aero.E., which is described in pages 61-62 of this Announcement, requires three or four terms of graduate study. Candidates for the degree B.M.E., in Option A, may be able to complete the entire program in a total of six academic years by starting aeronautical graduate courses during their fourth and fifth years. To accomplish this, a candidate should select his elective courses from the M.Aero.E. program and should also, if possible, carry out a fifth-year project in a related subject. This should be planned in consultation with the Class Adviser and a member of the Aeronautical Engineering Faculty. The privilege of taking graduate courses is restricted to undergraduates who fulfill the requirements stated on pages 62-63.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 11.

EMPLOYMENT AFTER GRADUATION

Graduates in mechanical engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering—to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen field.

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who does not receive a passing grade in every course in which he is registered, or fails in any term or summer session to maintain a minimum average of 70 per cent may be dropped from the University or placed on probation.

CURRICULUM (B.M.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Engineering 3001, Introductory Lectures	0	1	0
	Engineering 6110, Casting, Working, and Welding of Metals (or Engineering 3406)	2	1	2
	Total	17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	3	2½
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Engineering 3406, Materials Processing (or Engineering 6110)	2	1	2½
	Total	17		

In addition to taking these courses, all freshmen must satisfy the University requirements in physical training and in military science and tactics.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry (or Chemistry 402)	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Economics 107, Introduction to Economics (or Industrial Organization and Management, 3235)	3	3	0
	Psychology 101 (or Production Machine Tools 3404)	3	3	0
	Public Speaking 101 (or Gage Laboratory 3405)	3	3	0
	Total	20		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry (or Chemistry 301)	2	2	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 3235, Industrial Organization and Management (or Economics 107)	3	3	0
	Engineering 3404, Production Machine Tools (or Psychology 101)	2	1	2½
	Engineering 3405, Gage Laboratory (or Public Speaking 101)	1	0	2½
	Total	17		

In addition, all sophomores must satisfy the University requirements in physical training and in military science and tactics.

OPTION A

TERM 5	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3250, Industrial Accounting and Cost Control	4	2	5
	Engineering 3351, Mechanism	3	2	2½
	Engineering 3501, Engineering Thermodynamics	4	4	0
	Engineering 3502, Heat-Power Laboratory	2	0	5
	Engineering 1155, Applied Mathematics	3	3	0
	Total	19		
TERM 6	Engineering 1154, Advanced Strength of Materials	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3503, Heat Transfer and Thermal Measurements	3	2	2½
	Engineering 2331, Fluid Mechanics	3	3	0
	Total	18		
TERM 7	Engineering 1232, Engineering Materials Laboratory	3	1	2½
	Engineering 3353, Design of Machine Members	3	1	5
	Engineering 3504, Fuels and Combustion	2	2	0
	Engineering 3505, Refrigeration and Air Conditioning	3	2	2½
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6113, The Metallurgy of Casting, Working, and Welding	3	2	2
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 8	Engineering 3261, Industrial Engineering	3	1	5
	Engineering 3354, Design of Machines	3	1	5
	Engineering 3506, Steam Power	3	2	2½
	Engineering 3507, Combustion Engines	4	3	2½
	Engineering 4932, Electrical Engineering	3	2	2½
	Electives	2		
	Total	18		
TERM 9	Engineering 4933, Electrical Engineering	3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
	Electives	3		
	Law	3	3	0
	Total	18		
TERM 10	Engineering 4934, Electrical Engineering	3	2	2½
	History 166, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
	Electives	6		
	Engineering 3041, Nonresident Lectures	1	1	0
		19		
	Total for ten terms	180		

OPTION B

TERM 5	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3241, Industrial Statistics	3	2	2½
	Engineering 3250, Industrial Accounting and Cost Control	4	2	5
	Engineering 3351, Mechanism	3	2	2½
	Engineering 2331, Fluid Mechanics (or Methods Engineering 3262)	3	3	0
	Total	19		
TERM 6	Engineering 1154, Advanced Strength of Materials	3	3	0
	Engineering 1222, Engineering Materials	3	3	0
	Engineering 1231, Engineering Materials Lab.	3	1	2½
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3501, Engineering Thermodynamics	4	4	0
	Engineering 3262, Methods Engineering (or Fluid Mechanics 2331)	3	1	5
	Total	19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 7	Engineering 1232, Engineering Materials Lab.	3	1	2½
	Engineering 3263, Production Engineering	3	1	5
	Engineering 3353, Design of Machine Members	3	1	5
	Engineering 3502, Heat-Power Lab.	2	0	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6113, The Metallurgy of Casting, Working, and Welding	3	2	2
	Total	17		
TERM 8	Engineering 3264, Production Engineering	3	1	5
	Engineering 3270, Industrial Marketing	3	3	0
	Engineering 3356, Design of Machines	3	1	5
	Engineering 3503, Heat Transfer and Thermal Measurements	3	2	2½
	Engineering 3504, Fuels and Combustion	2	2	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Electives	2		
	Total	19		
TERM 9	Engineering 3254, Standard Costs	3	1	5
	Engineering 3508, Heat Power	3	2	2½
	Engineering 4933, Electrical Engineering	3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Project	3		
	Courses related to project	3		
	Total	18		
TERM 10	Engineering 3509, Heat Power	3	2	2½
	History 166, Science in Western Civilization	3	3	0
	Engineering 2902, Law	3	3	0
	Project	3		
	Electives	4		
	Engineering 3041, Nonresident Lectures	1	1	0
	Total	17		
	Total for ten terms	180		

School of Electrical Engineering

EQUIPMENT

THE LECTURE and recitation rooms of the School of Electrical Engineering occupy the greater part of Franklin Hall. Laboratories are in Franklin Hall, on the second floor of Rand Hall, and in two annexes. The library, which was established through a generous gift of the McGraw-Hill Book Company in memory of the first director of the School, and which is known as the Alexander Gray Memorial Library, is housed in Sibley Dome as a part of the combined Mechanical, Electrical, and Civil Engineering Library.

Laboratory facilities include the electrical machinery laboratories, with a great variety of both direct- and alternating-current machinery; the electrical measurements and standardization laboratory, equipped for instruction in the checking of meters and secondary standards and in the precise measurements of electrical and magnetic quantities; the radio and communication laboratory, including microwave and ultra-high-frequency laboratories; the industrial electronics laboratory, for the study of electronic power and control devices; the electronics apparatus and project laboratory, for the construction of electronic apparatus by students according to their own designs; the vacuum tube laboratory, for the construction of electron tubes; the servomechanism laboratory, for the study of closed loop control systems; the illumination laboratory; and the television and pulse technique laboratory.

In addition to these general laboratories, facilities available for instruction and research include the radio-astronomy laboratory, engaged primarily in basic research; the antenna laboratory, for the investigation of directional characteristics of antennas; the ionospheric laboratory; and the pipeline network analyzer, designed to solve problems of pressure and flow in fluid distribution systems by means of electrical analogies.

CURRICULUM

The curriculum leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the meaning and the application of those laws of nature which are basic in the practice of electrical engineering and to develop a general knowledge of the origins and the trends of modern society. Through the first seven terms, all students follow the same program of technical studies; in the

last three terms an interest in one of the principal subdivisions of electrical engineering is developed. Courses in administration and the humanities are distributed throughout the curriculum in accordance with the student's increasing comprehension.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

The curriculum reflects the convictions of the Faculty that the modern engineer is fully equipped only if his traditional ability to manage devices and processes is accompanied by a knowledge of men and an awareness of their needs.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program, providing periods of industrial experience interspersed among regular terms of study. The Program is described on page 11.

THE FRESHMAN YEAR

Since the curriculum of the freshman year in electrical engineering is essentially the same as those in mechanical engineering and engineering physics, transfer of a student between any two of these curricula may occur before the third term without loss of time. The freshman curricula in civil engineering and in chemical and metallurgical engineering differ to such an extent from that in electrical engineering that a transfer is almost certain to require a lengthening of the student's program.

CLASS ADVISERS

An experienced member of the Faculty acts as adviser to each new freshman class that enters the School of Electrical Engineering. With the sophomore year the class is assigned to another adviser who generally continues to serve until the class graduates, counseling each student in regard to curriculum, registration, scholarship, and other matters of the academic program. In addition, he tries to be helpful in the solution of personal problems which the student may bring to him.

Because responsibility for approval of the registration of each student is vested in the Class Adviser, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the student desires a program of courses which the Class Adviser does not approve, he may appeal by petition to the Faculty of the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

A student in the School of Electrical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of at least 70 per cent, may be dropped or placed on probation.

ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose elective courses to an extent constituting the approximate equivalent of one term of work. Some of the elective credit hours can be chosen without restriction, some must be nontechnical in the sense that they lie completely outside the field of engineering technology, and some must be taken in the School of Electrical Engineering. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole tends to expand the student's mental horizon and to develop him as a well-rounded citizen.

The program of the fifth year includes two three-hour courses designated as "Project," which are elective courses in the important respect that the student makes his own selection of the topic or problem which he will investigate under the general supervision of a Faculty member. It is expected that each student will choose a problem closely related to his major interest in electrical engineering.

Nine of the elective credit hours of the ninth and tenth terms must be selected from courses among a specific set of technical courses (page 50). Three of these nine credit hours must involve laboratory work.

Nine of the elective credit hours must be selected from fields of study which develop an engineer's interest outside electrical engineering and its supporting sciences. Approved examples are listed below. Other subjects may be approved upon petition.

Architecture	Fine Arts	Modern Languages
Astronomy	Geology	Music
Biology	Government	Ornithology
Botany	History	Paleontology
Dramatics	Industrial and Labor Relations	Philosophy
Economics	Journalism	Psychology
English	Limnology	Sociology
Entomology	Literature	Speech
Floriculture	Meteorology	Zoology

Elective hours beyond the eighteen enumerated above are designated as free electives. They may be chosen from among any courses in the University for which prerequisites are satisfied, including those in the foregoing list.

Credit hours in advanced military, air, or naval science and tactics may be counted, to the extent of nine, toward meeting the requirements of the baccalaureate degree. Six hours so credited are considered to lie within the free-elective area of the curriculum and three in the "non-technical" group.

GROUP COURSES

Each student's program for the last two terms usually includes several courses in the one of four technical groups which the student selects as representative of his major interest in electrical engineering, although the student is not required to confine his selection of electives to a single group among those included in the specified set. These groups, outlined on pages 50-51, are: Group I, Power Generation and Utilization; Group II, Industrial Electronics and Control; Group III, Radio and Communication; and Group IV, Physics.

The power generation and utilization group deals with electric power station equipment, transmission and distribution systems, protective equipment, high-voltage practice, and the characteristics and applications of typical electrical machinery.

The industrial electronics and control group deals with the theory and application of equipment utilizing the principles of electron emission, of control of electron flow in vacuum, and of ion and electron flow in gases. It concerns electronic control and instrumentation with both low- and high-frequency equipment.

The radio and communication group concerns the transmission of information by means of electricity. It includes the study of principles and equipment used in telephone and telegraph, telemetering, radio, television, sound recording and reproducing, radar, and microwave communication.

The physics group emphasizes, even more than do the other groups, basic physical principles rather than engineering applications. It is intended to prepare students for research and advanced development in electrical engineering. This group includes such subjects as electrostatic and electromagnetic fields, electromagnetic waves, and atomic and nuclear physics. It is open only to students who demonstrate unquestionable ability in science.

CURRICULUM (B.E.E.)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	2	3
	Engineering 3111, Descriptive Geometry	3	1	6
	Engineering 3402, Machine Tool Processes	2	1	2½
	(or Engineering 6110, Casting, Working, and Welding of Metals)	(2)	1	2
	English 111, Introductory Course	3	3	0
	Total	17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	Engineering 3112, Mechanical Drafting	3	1	6
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	(or Engineering 3402, Machine Tool Processes)	(2)	1	3
	English 112, Introductory Course	3	3	0
	Total	17		

In addition to the above courses, freshmen are required to take military science and tactics and physical training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 2131, Surveying	1	0	3
	Engineering 3327, Kinematics	2	2	0
	(or Engineering 1151, Mechanics)	(3)	3	0
	Economics 107, Introduction to Economics	3	3	0
	(or Engineering 3231, Accounting)	(3)	2	3
	Engineering 4110, Basic Electrical Engineering	3	2	3
	Total	17 (or 18)		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 4	Mathematics 607, Applied Mathematics for Electrical Engineers	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1151, Mechanics	3	3	0
	(or Engineering 3327, Kinematics)	(2)	2	0
	Engineering 3231, Accounting	3	2	2½
	(or Economics 107, Introduction to Economics)	(3)	3	0
	Engineering 4111, Basic Electrical Engineering	3	2	3
	Total	18 (or 17)		

In addition to the above courses, sophomores are required to take military science and tactics and physical training.

TERM 5	Engineering 1223, Engineering Materials	3	3	0
	Engineering 1152, Mechanics	3	3	0
	Engineering 3530, Thermodynamics	3	3	0
	Engineering 4112, Alternating-Current Circuits	3	2	3
	Engineering 4116, Electric-Current Laboratory	3	1	3
	History 165, Science in Western Civilization	3	3	0
	Total	18		
TERM 6	Engineering 1153, Mechanics of Materials	3	3	0
	3533, Heat Power Engineering	3	2	3
	Engineering 4121, Electron Tubes and Circuits	4	2	6
	Engineering 4216, Electrical Machinery Laboratory	4	2	3
	History 166, Science in Western Civilization	3	3	0
	Total	17		
TERM 7	Public Speaking 101, Public Speaking	3	3	0
	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4122, Electronic Circuit Elements	4	2	6
	Engineering 4131, Basic Communication Systems	2	2	0
	Engineering 4221, Alternating-Current Machinery	4	3	3
	Engineering 4113, Transmission Lines and Filters	3	3	0
	Total	19		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 8	Physics 214, Atomic, Nuclear, and Electronic Physics	3	3	0
	Engineering 4123, Electronic Systems	4	2	6
	Engineering 4226, Electrical Machinery Laboratory	4	2	3
	Psychology 101, Introduction to Psychology	3	3	0
	Engineering 4114, Transients in Linear Systems	3	2	3
	Total	17		
TERM 9	Technical Electives (see page 50)	6 or 3	–	–
	Nontechnical Electives (see page 46)	3 or 6	–	–
	Senior Project 4091	3	–	–
	Engineering Reports 4021	3	3	0
	Free Electives	6	–	–
	Total	21		
TERM 10	Technical Electives (see page 50)	3 or 6	–	–
	Nontechnical Electives (see page 46)	6 or 3	–	–
	Senior Project 4092	3	–	–
	Free Electives	6	–	–
	Nonresident Lectures	1	1	0
	Total	19		
	Grand Total for 10 Terms	180 hours		

TECHNICAL ELECTIVES (Satisfying 9 Hour Requirements)

Term	*Power Generation and Utilization*			
F	Engineering 4321, Machine Theory	3	3	0
S	Engineering 4326, Power Laboratory	3	1	3
F	Engineering 4341, Motor Control	2	2	0
F	Engineering 4361, Power Systems	3	2	3
S	Engineering 4362, Transmission of Electrical Energy	3	2	3
	Radio and Communication Engineering			
F	Engineering 4511, Radio and Communication Engineering	3	2	3
S	Engineering 4512, Radio and Communication Engineering	3	2	3
F	Engineering 4516, Radio and Communication Laboratory	3	1	3
S	Engineering 4517, Radio and Communication Laboratory	3	1	3

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
	Automatic Control and Industrial Electronics			
F	Engineering 4411, Electronic Control Equipment	3	2	3
S	Engineering 4421, Electronic Power Converters	3	2	3
F	Engineering 4711, Servomechanisms I	3	2	3
S	Engineering 4712, Servomechanisms II	3	2	3
	Physics			
F	Physics 210, Advanced Physics Laboratory	3	1	6
S	Physics 225, Electricity and Magnetism	3	3	0
F	Physics 243, Atomic and Molecular Physics	3	3	0
S	Physics 254, Electronic Properties of Solids and Liquids	3	2	3
	Illumination			
F	Engineering 4611, Introductory Illumination	3	2	3
S	Engineering 4612, Illumination Engineering	3	2	3
F	Engineering 4615, Illumination Seminar	2	2	0

WAR SERVICE EXPERIENCE AND COURSES

Provision is made for veterans to obtain toward the baccalaureate degree some credit for war service experience or courses. The student should consult his Class Adviser.

School of Chemical and Metallurgical Engineering

EQUIPMENT

THE SPECIALIZED training in chemical and metallurgical engineering is given in Olin Hall of Chemical Engineering and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin as a memorial to his son Franklin W. Olin, Jr. This modern and well-equipped building, with about 105,000 square feet of available floor space, provides lecture-room, recitation-room, and laboratory facilities for the instruction in chemical and metallurgical engineering. The unit operations laboratory, which is about one hundred feet long and fifty feet wide, extends through three floors and houses semi-plant scale equipment for both instruction and research. It is served by a traveling crane and by its own shops and analytical laboratory. A considerable part of the building is subdivided into unit laboratories for advanced and graduate students.

OUTLINE OF THE INSTRUCTION

The purpose of the instruction in this School is to provide a broad foundation of training in the fundamental subjects of mathematics, chemistry, and physics and in the essential principles and methods of engineering, and professional training in the specific fields of chemical and metallurgical engineering. In the required curriculum a certain amount of work in cultural subjects is included. By providing elective work in the later years, the curriculum makes it possible for the student to take additional courses either in subjects outside the field of his major interest or in special and advanced technical subjects within that field.

The first four terms provide thorough training in chemistry, mathematics, and physics and the other basic subjects on which the specific professional training is based. The later terms include more strictly technical and more advanced courses in engineering and in chemistry and the fundamental courses in the specific fields of chemical and metallurgical engineering. The last two terms include the more advanced work in en-

gineering and in the specialized fields. (For an outline of the course of study, see below.)

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75 per cent, may be dropped or placed on probation.

If in the opinion of the Faculty of the School concerned, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course, or from the University, at any time during the term.

EMPLOYMENT AFTER GRADUATION

Graduates in chemical engineering find employment in the design, development, operation, and administration of chemical engineering plants. There is also some demand for men with chemical engineering training for technical sales work in the chemical industries and for editorial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research chemists or research engineers.

Graduates in metallurgical engineering are employed in the various industries engaged in the winning and refining of metals, in the foundry industry, and in industries in which the heat treatment, welding, and forming of metals are important.

CURRICULUM (B.Ch.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3114, Drawing and Descriptive Geometry	2	1	2½
	Total	17		
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	3	3	0
	Chemistry 116, Introductory Chemistry Laboratory	3	0	7½
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3115, Drawing and Descriptive Geometry	2	1	2½
	Total	17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical training and military science and tactics.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 307, Introductory Organic Chemistry	3	3	0
	Chemistry 311, Organic Chemistry Laboratory	3	0	7
	Chemistry 220, Introductory Quantitative Analysis	3	3	0
	Chemistry 222, Quantitative Analysis Laboratory	3	0	7
	Physics 117, Electricity and Magnetism	3	2	2½
	Total	18		
TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	Chemistry 308, Introductory Organic Chemistry	3	3	0
	Chemistry 312, Organic Chemistry Laboratory	3	0	7
	Engineering 5501, Chem. Eng. Stoichiometry	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Physics 118, Physical Electronics and Optics	3	2	2½
	Public Speaking 101	3	3	0
	Total	20		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical training and military science and tactics.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	3	1	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 5203, Chem. Eng. Technology	2	2	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3 or 0	1	5
	Engineering 5303, Unit Operations of Chemical Engineering	3	3	0
	Total	20 (or 17)		
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	3	1	5
	Engineering 1153 Strength of Materials	3	3	0
	Engineering 5204, Chem. Eng. Technology	2	2	0
	Engineering 1256, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	0 or 3	1	5
	Engineering 5304, Unit Operations of Chemical Engineering	3	3	0
	Total	17 (or 20)		
TERM 7	Engineering 5353, Unit Operations Laboratory	3	2	3
	History 165, Science in Western Civilization	3	3	0
	Engineering 1233, Materials Testing Laboratory	3	1	2½
	Engineering 5102, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use	1	1	0
	Electives	5	–	–
	Total	18		
TERM 8	Engineering 5354, Unit Operations Laboratory	3	2	3
	History 166, Science in Western Civilization	3	3	0
	Engineering 5104, Chemical Engineering Thermodynamics	3	3	0
	Engineering 4931, Electrical	3	2	2½
	Engineering 5701, Plant Inspections	1	–	–
	Electives	4	–	–
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 9	Engineering 4932, Electrical	3	2	2½
	Engineering 5603, Chemical Equipment	2	2	0
	Engineering 5605, Chemical Plant Design	2	1	3
	Engineering 5503, Chemical Engineering Computations	2	2	0
	Engineering 5953, Senior Project	3	0	9
	Engineering 3253, Cost Accounting	3	2	3
	or			
	Electives	(3)	–	–
	Electives	3	–	–
	Total	18		
TERM 10	Engineering 4933, Electrical	3	2	2½
	Engineering 5504, Chemical Engineering Computations	2	2	0
	Engineering 5604, Chemical Equipment	2	2	0
	Engineering 5606, Chemical Plant Design	2	1	3
	Engineering 5954, Senior Project	3	0	9
	Electives	3	–	–
	or			
	Engineering 3253, Cost Accounting	(3)	(2)	(3)
	Electives	3	–	–
	Total	18		

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

METALLURGICAL ENGINEERING CURRICULUM (B.Met.E.)

TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	General Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3114, Drawing and Descriptive Geometry	2	1	2½
	Engineering 3403, Fundamentals of Machine Tools	1	0	2½
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	3	3	0
	Chemistry 116, Introductory Chemistry Laboratory	3	–	7½
	General Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3115, Drawing and Descriptive Geometry	2	1	2½
	Total	17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical training and military science and tactics.

TERM 3	Chemistry 220, Introductory Quantitative Analysis	3	3	0
	Chemistry 222, Quantitative Analysis Laboratory	3	0	7
	General Physics 117, Electricity and Magnetism	3	2	2½
	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Geol. 712, Metallurgical Raw Materials	3	3	0
	Engineering 6111, Introductory Metallurgy	2	1	2
	Total	17		
TERM 4	Chemistry 301, Engineering Chemistry (Organic)	2	2	0
	General Physics 118, Physical Electronics and Optics	3	2	2½
	Engineering 1156, Applied Mathematics	3	3	0
	Engineering 1151, Mechanics	3	3	0
	Economics 107, Introduction to Economics	3	3	0
	Public Speaking 101	3	3	0
	Total	17		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical training and military science and tactics.

TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	3	1	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3	1	5
	Engineering 6501, Metallurgical Calculations	2	2	0
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	3	1	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 1233, Engineering Materials Laboratory	3	1	2½
	Engineering 1256, Materials of Construction	3	3	0
	Engineering 6811, Introductory Metallography	3	1	5
	Total	18		
TERM 7	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use and Patents	1	1	0
	Engineering 6311, Physical Metallurgy	2	2	0
	Engineering 6351, Physical Metallurgy Laboratory	3	1	5
	Engineering 6253, Unit Processes in Metallurgy	3	1	2½
	Engineering 6203, Smelting and Refining	3	3	0
	Electives	3		
	Total	18		
TERM 8	Engineering 6114, Metallurgy of Casting, Working, and Welding	3	2	2
	Engineering 6254, Unit Processes in Metallurgy	2	1	2½
	Engineering 6204, Smelting and Refining	3	3	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6312, Physical Metallurgy	2	2	0
	Electives	6	0	0
	Total	19		
TERM 9	Engineering 3255, Elements of Industrial Accounting	3	1	5
	Engineering 4932, Electrical Engineering	3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Engineering 6221, Advanced Process Metallurgy	2	0	0
	Engineering 6953, Senior Project	3	0	7½
	Electives	6	–	–
	Total	20		
TERM 10	Engineering 4933, Electrical Engineering	3	2	2½
	Engineering 6602, Metallurgical Design	3	3	0
	Engineering 6701, Plant Inspections	1	0	0
	Engineering 6954, Senior Project	3	0	7½
	History 166, Science in Western Civilization	3	0	0
	Electives	6		
	Total	19		

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

OPTIONS IN CHEMICAL AND METALLURGICAL ENGINEERING

A student in chemical engineering or in metallurgical engineering may select his elective courses in any one of several optional fields to provide somewhat more extensive training than is afforded by the required courses in the curriculum. The student may also, if he so desires, arrange his elective work to provide a cultural background broader than that given by the required courses. The selection of electives must be approved by the Class Adviser.

The Graduate School of Aeronautical Engineering

THE PRIMARY objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out intensive research and development engineering in the aeronautical and related industries and in aeronautical scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more-than-average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the aeronautical engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, N.Y. In addition, certain periods of employment at the Laboratory are offered to aeronautical engineering students—usually during their summer vacations. Students are urged to take advantage of such employment, if it is available. It is also possible that certain experimental equipment of the Laboratory will occasionally be available to graduate students in connection with their original research.

The Graduate School of Aeronautical Engineering is equipped with a fluid-mechanics laboratory on the campus in Ithaca for fundamental scientific research in fluid mechanics and aerodynamics.

ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made directly to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the office of the Director. It should be sent to the Director of the Graduate School of Aeronautical Engineering.

Students who desire to work for the degree Ph.D. with aeronautical engineering as their major subject must be admitted to the Graduate

School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

The degree M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and candidates for this degree are not necessarily admitted to the Graduate School of the University. The degree is awarded upon satisfactory completion of a required curriculum of studies and an acceptable thesis. Candidates for this degree do not have Special Committees and do not select a minor subject.

CURRICULUM

The aeronautical engineering curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree Master of Aeronautical Engineering and to the degree Doctor of Philosophy with aeronautical engineering as the major subject.

A. *Course of Study Leading to the Degree M.Aero.E.*

The curriculum requirement for the degree M.Aero.E. is the successful passing of a series of courses, outlined below, or examinations in these subjects. Although the list of required subjects is such as to occupy ordinarily three or four terms of graduate study, the residence requirement has been set at one year (two terms), so that students who enter the School with exceptional preparation, or are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

When the student desires to satisfy a requirement by examination (rather than by passing a course), he should request the Faculty of the School to schedule such an examination.

It is suggested that the recommended program of courses outlined below be supplemented by additional aeronautical engineering courses and electives, so as to result in a balanced program of approximately sixteen credit hours a term.

This program of aeronautical engineering studies is not only applicable to much of the standard engineering work in the aeronautical industry, but beyond that the course is planned to increase the student's facility in the use of the basic sciences in aeronautical engineering and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

Required Subjects for M.Aero.E.

	Credit Hours
Mathematics 611 and 612, Higher Calculus for Engineers and Physicists	6
or	
Engineering 1170 and 1171, Advanced Mechanics	6
Engineering 7101, Mechanics of Airplanes	4
Engineering 7102, Mechanics of Airplanes	4
or	
Engineering 7203, Aerodynamics of Power Plants	3
or	
Engineering 4991, Electronic Engineering	3
Engineering 7204, Gasdynamics	4
Engineering 7301, Theoretical Aerodynamics I	3
Engineering 7401, and 7402, Airplane Structures	6
Engineering 7403 and 7404, Airplane Design	2
Electives chosen from List A below	12

Electives: List A

Engineering 7205, Kinetic Theory	2
Engineering 7302, Theoretical Aerodynamics II (Wing Theory)	3
Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids)	3
Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids)	3
Engineering 7305, Aerodynamics of Compressible Viscous Fluids	2
Engineering 7405, Aero-Elastic Problems	3
Engineering 7406, Special Methods of Structural Analysis	2
Engineering 1162, Mechanics of Vibration	3
or	
Engineering 1170, 1171, Advanced Mechanics	3, 3
Engineering 1163, 1164, Applied Elasticity	3, 3
Engineering 1167, Theory of Plates and Shells	3
Engineering 1168, Analogies in Boundary Value Problems	2
Engineering 1165, Theory of Elastic Stability	3
Engineering 1181, Current Literature in Applied Mechanics	3
Engineering 1261, Plastic Behavior of Solids	3
Mathematics 621, 2, Mathematical Methods in Physics	5, 5
Mathematics 641, 2, Partial Differential Equations	3, 3
Physics 242, Analytical Mechanics	3
Physics 243, Atomic and Molecular Physics	3
Physics 475, Theoretical Mechanics	3
Physics 090, Special Laboratory Work	(arranged)

B. *Courses Leading to the Degree Ph.D.*

Students will be admitted to candidacy for the degree Ph.D. as set forth in the current *Announcement of the Graduate School.* General requirements such as residence, major and minor subjects, requirements in foreign languages, qualifying examinations, and thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the Announcement.

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students

holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The courses of study in engineering physics and in mechanical engineering (Option A) are especially recommended to students who expect to enter this School after graduation.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs. The following courses are recommended for this purpose:

Engineering 7101, 7102	Mechanics of Airplanes
Engineering 7203	Aerodynamics of Power Plants
Mathematics 611, 612	Higher Calculus for Engineers and Physicists
or	
Mathematics 621, 622	Mathematical Methods in Physics
Engineering 7204	Gasdynamics
Engineering 7401, 7402	Airplane Structures
Engineering 7403, 7404	Airplane Design
Engineering 1170, 1171	Advanced Mechanics
Engineering 1162	Mechanics of Vibration
Engineering 1165	Theory of Elastic Stability
Physics 242	Analytical Mechanics

To be admitted to any of the graduate courses listed above, an undergraduate student must

(1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University,

(2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research, and

(3) have his admission to the courses recommended by the Director of the Graduate School of Aeronautical Engineering (or the chairman of the department concerned) and approved by the Dean of the College of Engineering.

It is further recommended that all students who expect to enter the Graduate School of Aeronautical Engineering include in their programs the following courses, or their equivalents:

Mathematics 201	Differential Equations
Engineering 1111	Engineering Mechanics
Engineering 1155	Intermediate Mechanics
Engineering 1151, 1152, 1153	Mechanics and Strength of Materials
Engineering 3530	Thermodynamics

Department of Engineering Physics

OBJECTIVES

THE DEPARTMENT of Engineering Physics is a new department constituted so as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and that of conventional engineering practice. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

FACULTY

The administrative arrangement of the Department is such that the Faculty of the Department includes members of the science departments of the College of Arts and Sciences and members of the several schools of engineering in the College of Engineering who are particularly interested in the objectives of the Department.

LABORATORY FACILITIES

The Department of Engineering Physics has a fully equipped laboratory of electron microscopy, including two large research type electron microscopes and equipment for both research on the instrument itself and on applications to problems in physics, chemistry, biology, and engineering materials. Facilities are also available for study in applied electron optics.

The Department also maintains a laboratory with much special equipment for the study of the elastic properties of single metal crystals, of elastometers, plastics, and similar materials, and of other phenomena related to the physics of the solid state.

In addition, students carrying out their project study have access to the other laboratories of the College of Engineering and to those of the College of Arts and Sciences as may be desirable.

CURRICULUM

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of study

is designed to combine the broad, basic, scientific and analytical training of the physicist with the knowledge of the properties of materials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental science, namely, mathematics, physics, and chemistry; the properties and treatment of material; and engineering practice.

For training in research, the student terminates the course by carrying out a semi-research project in a special field of his own choice, under the direction of a Faculty member who is an authority in the selected field. There are a great variety of these special fields in physics and engineering. They include topics in electron physics, atomic physics, physical optics, electron optics and applications including electron microscopy, X-rays and crystal structure, spectroscopy, nuclear physics, engineering electronics, communications, electrical machinery, ultra high-frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, physical metallurgy, thermodynamics, aerodynamics, airplane structure, etc.

ELECTIVE COURSES

Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to advance in some technical fields beyond the level provided by the required courses as his interest in such fields develops. To permit this, at least eighteen hours are provided to cover the semi-research project and the technical electives which may be selected, with the permission of the student's Adviser, from the following subjects: physics, mathematics, chemistry, physical metallurgy, advanced mechanics and elasticity, fluid mechanics, aerodynamics, heat power, communications, industrial electronics, servomechanism theory, ultra high frequency. The choice will depend largely on the student's particular ability or interest.

The curriculum provides for a minimum of thirty hours of liberal courses. Of these, there are twelve hours required and eighteen hours to be elected. These electives may be chosen from the following subjects: astronomy, biology, botany, economics, English, government, history, industrial and labor relations, literature, landscape architecture, music appreciation, philosophy, psychology, sociology, speech. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole assists in expanding the student's mental horizon and in developing him as a well-rounded citizen. Students who pass the proficiency examination of the Department of Modern Languages may substitute six hours of other liberal electives in place of the language requirement. Students who wish to continue the modern language studied in high school should take the College Board Achievement Test in that language; otherwise, they will be asked to take a proficiency

examination at the University. Further information is given in the section on "Proficiency Requirements" in the *Announcement of the College of Arts and Sciences.* Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

In addition, a maximum of nine hours of free electives is provided which may be chosen from any courses in the University which are open to the student, except, however, that not more than six credit hours toward the baccalaureate degree will be allowed in advanced military science and tactics or in naval science.

CLASS ADVISERS

Members of each entering class in the engineering physics curriculum are assigned to an Adviser who will counsel and supervise each student in matters connected with choice of elective courses, registration, scholarship, and other matters of importance encountered during the student's entire college career. The personal relationship between the Adviser and the student and the Adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

SCHOLASTIC REQUIREMENTS

A student enrolled in the engineering physics curriculum is expected to maintain the following minimum scholastic requirements:

(1) receive a passing grade in every course for which he is registered,

(2) maintain each term a weighted average of at least 75%,

(3) exhibit natural aptitude and competence in the basic subject matter of the curriculum.

A student failing to satisfy these requirements may be put on probation, or refused permission to continue his studies in the Department.

THE ENGINEERING PHYSICS CURRICULUM

			CONTACT HOURS	
		CREDIT HOURS	LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	5
	Liberal Elective	3	3	0
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Chemistry	3	3	2½
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	5
	Engineering 3403, Fundamentals of Machine Tools	1	0	2½
	Liberal Elective	3	3	0
	Total	18		
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Introduction to Organic Chemistry	2	2	0
	Engineering 1151, Statics	3	3	0
	A modern foreign language	6	2	6
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	Total	19		
TERM 4	Mathematics 201, Elementary Differential Equations	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	Physical Chemistry	3	3	0
	Engineering 1153, Mechanics of Materials	3	3	0
	Physics 208, Physical Mechanics and Properties of Matter	3	3	0
	Engineering 4981, Electric and Magnetic Circuits	3	2	2½
	Total	18		

In addition to these courses, students must satisfy the University's requirements in military science and tactics and physical training for the first four terms.

TERM 5	Physics 225, Electricity and Magnetism	3	3	0
	Mathematics 611, Higher Calculus	3	3	0
	Engineering 8121, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4982, Alternating-Current Circuits	3	2	2½
	Engineering 4116, Electric-Circuit Laboratory	3	2	3
	Elective, Liberal or Free	3		
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 6	Physics 242, Analytical Mechanics	3	3	0
	Mathematics 612, Higher Calculus	3	3	0
	Engineering 8122, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4121, Electron Tubes and Circuits	3	2	2½
	Engineering 4126, Electronics Laboratory	2	0	3
	Elective, Liberal or Free	3		
	Total	17		
TERM 7	Physics 243, Atomic and Molecular Physics	3	3	0
	Mathematics 621, Mathematical Methods in Physics	4	4	0
	Engineering 1201, Engineering Materials	3	3	0
	*Engineering 4932, Electrical Machinery	3	2	3
	Elective	3		
	Total	16		
TERM 8	Physics 254, Electronic Properties of Solids and Liquids	3	3	0
	Physics 210, Advanced Laboratory	3	1	5
	Mathematics 622, Mathematical Methods in Physics	4	4	0
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Elective	3		
	Total	16		
TERM 9	Physics 210, Advanced Laboratory	3	1	5
	Engineering 1202, Advanced Materials	3	3	0
	Engineering 8051, Project, and Electives	9		
	Elective, Liberal or Free	3 or 6		
	Total	18 or 21		
TERM 10	Physics 258, Mechanics of Continuum	3	3	0
	Engineering 8052, Project, and Electives	9		
	Elective, Liberal or Free	6 or 3		
	Total	15 or 18		

*Engineering 4932 may be postponed until Term 9 and an elective substituted in Term 7.

Description of Courses

THE COURSES listed in the preceding curricula are described in the following sections of this Announcement. Courses are described under the heading of the school or college in which the course is offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences. Courses in military science and tactics and physical training, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

1. Engineering Mechanics and Materials
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aeronautical Engineering
8. Engineering Physics

General courses of instruction required by some or all of the schools within the College of Engineering but given in other colleges of the University are described on pages 117-125, inclusive.

For courses in other colleges not described here, to be taken as electives, see the Announcement of the appropriate college.

ENGINEERING MECHANICS AND MATERIALS

Courses described in this section are given by the Department of Engineering Mechanics and Materials. They constitute a major part of the stem of basic engineering science prescribed for all engineering students and are directed toward the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

MECHANICS OF ENGINEERING

Messrs. CAMERON, CONWAY, CRANCH, CUYKENDALL, FAY, GUNDER, HOWELL, PERKINS, and STEG.

1134. *MECHANICS OF ENGINEERING—STRENGTH OF MATERIALS.* Required of all civil engineering students. Credit three hours. Three recitations a week; prerequisite, 1153. Elastic curves, safe loads, columns, flexure of beams. Problems showing the application of engineering design.

1145. *APPLIED ENGINEERING MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 163 and Mechanics 1134. Elementary differential equations and their applications to engineering problems in the civil engineering fields. Analysis of numerical data and their graphical representation.

1151. *MECHANICS OF ENGINEERING—STATICS.* Credit three hours. Prerequisites, Physics 115 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. Vector methods.

1152. *MECHANICS OF ENGINEERING—DYNAMICS.* Credit three hours. Prerequisites, 1151, 1155. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational and general plane motion of rigid bodies. Impulse-momentum, work-energy, virtual work. Vector methods. (The section of this course for Civil Engineering students is offered in the spring term only and does not require 1155 as a prerequisite.)

1153. *MECHANICS OF MATERIALS.* Credit three hours. Prerequisite, 1151. Stress and strain, tension, compression, and shear, riveted and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports.

1154. *ADVANCED STRENGTH OF MATERIALS.* Credit three hours. Three recitations a week. Prerequisite, Course 1155. Strength, stiffness and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED MECHANICS.* Credit three hours. Three recitations a week. Prerequisites, 1152 and 1153. The formulation and solution of problems, arising in mechanical engineering, which involve the use of elementary differential equations, and Fourier series. Emphasis is placed on numerical as well as analytical methods of solution.

1156. *APPLIED MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisite, Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods, and special functions.

1159. *ADVANCED MECHANICS LABORATORY.* Credit three hours. Two 2½ hour laboratories per week, as arranged. A course for graduate students; undergraduates must have the consent of the instructor. The course entails approximately six reports covering the following subjects: (1) Analysis and design of experiments, statistics of testing; (2) amplification and recording of information, frequency response of amplifiers and recording apparatus; (3) experimental stress analysis using SR-4 resistance strain gages, stress coat and photoelasticity; (4) variation of properties of materials with temperature, measurement, and control of temperature; (5) vibrations of rods, plates, shells, etc., analysis of vibrations; (6) at least one problem in the student's own special field.

1162. *MECHANICS OF VIBRATION.* Elective for graduates and qualified undergraduates. Credit three hours. Three recitations a week. Prerequisite, 1155 or equivalent. The characteristic phenomena of mechanical vibrations encountered in engineering and their quantitative investigation, illustrated by a group of typical vibrating systems. Representation of simple harmonic motion; combination of several simultaneous motions; simple cases of free and forced vibrations, with damping; resonance; principles of transmission and isolation of vibration; systems of variable mass and variable elasticity; systems with several degrees of freedom; vibrations of taut wires, bars, beams, rings, membranes, and plates; relation of vibration and noise; self-excited vibration; detection and measuring instruments; examples of diagnosis and preventive measures.

1163, 1164. *APPLIED ELASTICITY.* Elective for graduates and qualified undergraduates. Continuing two terms. Credit three hours each term. Spring and fall terms respectively. Three recitations a week. Prerequisite for 1163, permission of the instructor; for 1164, 1163 and 1170 or a basic knowledge of Fourier series. General analysis of stress and strain, Airey's stress functions in cartesian and polar coordinates, trigonometric and strain energy methods; torsion of bars of arbitrary section, the membrane analogy, the Griffith-Taylor graphical method, effects of grooves, torsion of thin tubes, stress in thick cylinders and disks due to pressure, heating, and rotation; beams on elastic foundations; revision of Castigliano's theorem and virtual displacements, application to frameworks and rings, closed rings under hydrostatic pressure.

1165. *THEORY OF ELASTIC STABILITY.* Elective for graduates and qualified undergraduates. Credit three hours. Three recitations a week. Mathematical analysis of the conditions under which columns, beams, rings, tubes, thin plates, and thin curved shells may fail by general or local buckling. Applications to mechanical, civil, naval, and aeronautical structures.

1167. *THEORY OF PLATES AND SHELLS.* Credit three hours. Spring term. Three recitations a week. Prerequisite, 1155 or a knowledge of elementary differential equations and permission of the instructor. Historical introduction; differential equations for the deflection of a plate in cartesian and polar coordinates; methods of solution for cases of uniform and nonuniform thickness; Navier and Levy solutions for simply supported rectangular plate, rectangular plate with clamped edges; temperature stresses; the membrane method of Marcus and applications; strain energy of a bent and stretched plate, application to large deflection theory, Föppls methods. Symmetrical deformation of cylindrical shells, temperature stresses, pressure vessels; buckling under radial pressure and end thrust; deformation of shells without bending, conical, ellipsoidal, and toroidal shells.

1168. *ANALOGIES IN THE SOLUTION OF BOUNDARY VALUE PROBLEMS OF ENGINEERING.* Credit two hours. Spring term. One recitation, one laboratory a week. Elementary theory of photoelasticity. The membrane, electrical potential and hydrodynamic analogies; X-ray diffraction and other methods of stress evaluation.

1170. *ADVANCED MECHANICS.* Credit three hours. Fall term. Three recitations a week. Prerequisite, 1155. The formulation and solution of problems in engineering mechanics by vector methods, Lagrange's equations, generalized coordinates, Fourier series. Conservative systems.

1171. *ADVANCED MECHANICS.* Credit three hours. Spring term. Three recitations a week. Continuation of 1170. Nonconservative systems, energy methods, impact loads, operational methods.

1172. *SELECTED TOPICS IN ADVANCED MECHANICS.* Offered as required. Credit as arranged. Special studies in selected topics.

1175. *INTRODUCTION TO NONLINEAR MECHANICS.* Credit three hours. Spring term. Three recitations a week. Prerequisite, a knowledge of elementary ordinary differential equations. A study of the methods of analysis of the nonlinear electrical and mechanical systems frequently encountered in practice, including criteria for stability and a comparison between linear and nonlinear methods. Emphasis will be placed upon the discussion of a number of problems rather than upon the coverage of a broad field.

1181. *ANALYSIS OF CURRENT LITERATURE IN APPLIED MECHANICS.* Open to graduate students only. Registration by permission of instructor only. Credit three hours. Fall term. Three recitations a week. Special training in the critical analysis and interpretation of technical papers currently appearing in the field of applied mechanics. Evaluation of assumptions, procedures, and conclusions of such papers. The preparation of critical discussions.

1198, 1199. *PROJECT.* Total credit 6 hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering mechanics. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

ENGINEERING MATERIALS

Messrs. GUNDER, JEFFREY, MASON, MOYNIHAN, SACK, SLATE, STUART, and WIEGANDT.

1201. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, Chemistry 301 and 402, Engineering Mechanics 1122. A lecture course treating the physical and electrical properties of engineering materials with special emphasis on the relation of these properties to the structure of the materials and to their forming, working, heat treatment, etc.

1202. *ADVANCED ENGINEERING MATERIALS.* Credit three hours. Fall term. Primarily for fifth-year students in engineering physics; others with consent of instructor. Discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semiconductors, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids, and current literature is included in the assignments.

1211. *MATERIALS OF CONSTRUCTION.* Required of all civil engineers. Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 1153. A study of the basic chemical and physical properties of various engineering materials including cast iron, wrought iron, steel, aluminum, magnesium, stone, brick, tile, and other building materials. Laboratory testing of these materials so conducted as to emphasize both the techniques of testing and the evaluation of fundamental material properties. Behavior of the material both as an isolated element and as a structural component. Tensile, compressive, torsional, shearing, and flexure tests.

1212. *MATERIALS OF CONSTRUCTION.* Required of all civil engineers. Credit three hours. One recitation and two laboratory periods a week. Prerequisite, 1211. Should be preceded by or taken concurrently with 2715. A continuation of 1211 with special emphasis on timber, cement, concrete, and elemental concrete structural members. Emphasis is placed upon the laboratory studies of the fundamental characteristics and behavior of the materials.

1215. *MATERIALS SEMINAR.* Elective. Open to specially selected seniors or graduate students. One to six hours credit. One 1-hour period a credit hour. Abstraction and discussion of technical papers and publications in the materials field.

1216. *STRUCTURE AND PROPERTIES OF MATTER.* Credit two hours. Fall term. Primarily for graduate students in any branch of engineering. Prerequisite, permission of the instructor.

1217. *ADVANCED CONCRETE.* Spring term. Credit optional; two hours for lectures only or three hours for lectures and laboratory. Prerequisite, 1212 or equivalent. Lectures and discussions on such topics as air entrainment, petrography, durability, chemical reactions, and properties of aggregates.

1221. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, Physical Chemistry 402 or its equivalent. A lecture course in engineering materials dealing with the making, shaping, and treating of metals and alloys and the effects produced thereby on their physical and mechanical properties which govern their adaptability for specific service require-

ments. Following the development of the general principles involved, their specific application to iron and steel is examined and explained.

1222. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, 1221 and Organic Chemistry 301 or their equivalent. A lecture course continuing the work of 1221 as applied to high alloy steels, tool and die steels, cast irons, the nonferrous metals and alloys. The effects of corrosion and temperature on the properties of materials are discussed. Included in the course also are the following nonmetallic materials: fuels and their combustion, refractories, cementing materials and concrete, wood, rubber, plastics, and lubricants.

1223. *ENGINEERING MATERIALS.* Credit three hours. Two lectures and one laboratory period each week. Prerequisites, Organic Chemistry, Chemistry 301, and Physical Chemistry, Chemistry 402. A study of the properties of ferrous and nonferrous metals and alloys, and nonmetallic materials such as cementing materials and concrete, plastics, wood, rubber, thermal and electrical insulating materials. Special attention will be given to electrical and magnetic properties. The laboratory will illustrate materials testing, including mechanical and electrical properties of these materials.

1231. *ENGINEERING MATERIALS LABORATORY—METALS AND ALLOYS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1221 and 1153. May be taken simultaneously with the latter course.

A course dealing with materials testing and the properties of metals and alloys. The following types of tests with testing machines and strain measurement will be performed: tension, torsion, compression, bending, impact, fatigue, hardness and ductility. The relation between the properties, structure, selection, inspection and use of metals and alloys will be shown by the following experiments: carbon steels, cast irons, heat treatment, nonferrous metals and alloys, metallography, spectrography, radiography, and magnaflux.

1232. *ENGINEERING MATERIALS LABORATORY — NONMETALLIC MATERIALS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1222 and 1231. A course dealing with materials testing and the properties, composition, selection and use of the following nonmetallic materials: oils and lubricants, fuels (solid, liquid, and gaseous), plastics, wood, cementing materials, and concrete.

1233. *ENGINEERING MATERIALS LABORATORY—MATERIALS TESTING.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1255, 1256, and 1153. May also be taken simultaneously with the latter two courses.

A course dealing with materials testing and the determination of the properties of materials and their significance.

Laboratory work includes the study of construction, use, and calibration of testing machines; the testing of representative materials in tension, torsion, bending, compression, impact, fatigue, creep, and hardness; magnetic, microscopic, and radiographic inspection; photoelastic methods; testing of lubricants; lubrication and bearing tests.

1251. *ENGINEERING MATERIALS RESEARCH.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, 1231, 1232, or 1233, or consent of instructor.

This course is open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in materials laboratory or who have other suitable background to enable them to carry on special problems and investigations under the supervision of the staff.

1252. *APPLICATIONS OF ENGINEERING MATERIALS.* Credit three hours. Two lectures and one recitation period each week. Prerequisite, 1231. This course covers the applications of physical metallurgy to problems in engineering and will deal with all processing operations including casting, mechanical working and heat treatment, and the subsequent inspection and use of ferrous and nonferrous metals and alloys. The significance and control of mechanical properties will be emphasized.

1253. *PHYSICS OF ENGINEERING MATERIALS.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, 1231, 1232, and 1233.

This course is open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in engineering materials and physics to enable them, under staff supervision, to carry on special problems and investigations in the field of the physical properties of engineering materials and the application of physical methods to production control.

1255, 1256. *MATERIALS OF CONSTRUCTION.* Primarily for students in Chemical and Metallurgical Engineering. Credit three hours each term. Two terms. Lectures. Prerequisites or parallel courses, Physical Chemistry 403, 404.

An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions.

Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

1261. *PLASTIC BEHAVIOR OF SOLIDS.* Primarily for graduate students; for undergraduates with the consent of the instructor. Credit three hours. Fall term. Phenomenological classification of plastic behavior; experimental procedures. Conditions for plastic flow; stress distribution and displacements, boundaries between plastically and elastically strained regions. Physical concepts of plasticity; single crystals and dislocations; relaxation phenomena; grain boundaries; mobility of molecules in plastics and elastometers; phenomena at transition points; chemical reactions.

1298, 1299. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering materials. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

CIVIL ENGINEERING

Required courses in the civil engineering curriculum given outside the College of Engineering are as follows:

Chemistry 105, 106, 301, 402 (pp. 119-120)
Economics 107. Introduction to Economics (p. 121)
Economics 203. Money, Currency, and Banking (p. 121)
English 111, 112. Introductory Course (p. 121)
Geology 113. Engineering Geology (p. 121)
History 165, 166. Science in Western Civilization (p. 121)
ILR 293. Survey of Industrial and Labor Relations (p. 121)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 122)

DESCRIPTIVE GEOMETRY AND DRAWING

Mr. JENKINS and others.

2001. *DRAWING.* Credit three hours. Fall term. A course in the fundamentals

of the graphic language as used in engineering. It is laid out to include the care and use of drafting instruments, freehand and technical sketching, and print reproduction. Text: *Engineering Graphics,* Rule and Watt.

2002. *DRAWING.* Credit three hours. Spring term. Prerequisite, 2001. Instruction and drill in the fundamental conception of descriptive geometry, dealing with the graphic solution of advanced space problems, both theoretical and practical. This course develops a complete grasp of the principles of projection and gives further training in visualization. Practical civil engineering problems such as topographic mapping, structural drafting, and charts and graphs are included in the course.

2004. *ADVANCED DRAWING.* Elective for upperclassmen. Credit one to three hours. Either term. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to nontechnical persons.

2005. *CARTOGRAPHY.* Elective for upperclassmen. Credit three hours. Fall term. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales, and construction of planimetric, topographic, and chorographic maps from survey notes and data from aerial photographs. This is a first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation. Some work will be done with cartograms, science maps, block diagrams, scale models, and globes.

2006. *MAP REPRODUCTION.* Elective for upperclassmen. Credit three hours. Spring term. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The various methods of map reproduction are studied, with sufficient general theory incorporated to afford an understanding of the principles involved. The selection, evaluation, and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

SURVEYING

Messrs. McNAIR, PESCE, SPRY, and others.

2111. *ELEMENTARY SURVEYING.* Required of all civil engineering students. Credit two hours. Spring term. Two recitation or field periods a week. Use and care of steel tape, level and transit; note keeping; fundamental surveying methods; measurement of lines, angles, and differences of elevation; mapping. tions; plane table mapping. Text: *Advanced Surveying, Vol. II,* Rayner.

2112. *ADVANCED SURVEYING.* Required of all civil engineering students. Credit three hours. Fall term. Prerequisite, 2111. Two recitations and one field or mapping period a week. Principles of land surveying; topographic, hydrographic, geodetic, mine, and city surveys; elements of practical astronomy; map projections; plane table mapping. Text: *Advanced Surveying, Vol. II,* Rayner.

2113. *ROUTE AND AERIAL SURVEYING.* Required of all civil engineering students. Credit three hours. Spring term. Prerequisite, 2112. One recitation and two field or computation periods a week. Principles of route surveying. Theories of simple, transition, and vertical curves, and the determination of volumes of earthwork are combined with appropriate field problems. The paper location of a route is made on a given map, and then the profile and cross-sections serve as a basis for earthwork computations. Elementary principles of photo-interpretation and photogrammetry. Texts: *Field Engineering,* Searles, Ives, and Kissan; *Advanced Surveying, Vol. II,* Rayner.

2114. *SUMMER SURVEY.* (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Required of all civil engineering students, following the sophomore year. Credit five hours. Field and office work six days a week. Attendance for five weeks. Date of the beginning of the camp will be announced in the spring term. Prerequisite, 2113. Practical experience in surveying under field conditions. An extensive topographic survey with emphasis on transit-stadia and plane table-stadia methods is made, and the corresponding map is drawn. A hydrographic survey of Cayuga Lake is executed, and maps are made. A complete route survey is made including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards, including base-line taping, triangulation with repeating and direction type optical-reading theodolites, precise traverse with subtense bar, and precise leveling. Astronomic observations for azimuth and position are made and results computed. Each student takes part in all aspects of the work.

2115. *LEAST SQUARES: ADJUSTMENT OF OBSERVATIONS.* Elective for upperclassmen and graduate students. Credit three hours. Fall term. Three recitations a week. The course is designed for students who have experimental investigations in view. The fundamental principles of least squares with application to the adjustment of typical surveying work, such as leveling and triangulation. Applications are also made to problems in fields such as physics, astronomy, and mechanics, with some attention to the derivation of empirical formulas. Text: *Practical Least Squares,* Leland.

2117. *GEODESY AND GEODETIC LABORATORY.* Elective for upperclassmen and graduates. Credit three hours. Lectures, reading, discussions, and laboratory work three periods a week. Prerequisite, consent of instructor. A course for the consideration of special problems in geodetic work: precise leveling; deflection of the plumb line; figure of the earth, determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS.* Elective for upperclassmen and graduate students. Credit three hours. One recitation and two laboratory periods a week. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL.* Elective for upperclassmen and graduates. Credit three hours. Spring term. Prerequisite, 2113. Lectures, reading, and field work. The basic principles of barometric, trigonometric, spirit, and electronic leveling. Determination of sea level. A study of hysteresis and swing corrections in precision altimeters; the effect of meteorological conditions on barometric readings; the relationship of frequency of readings and horizontal and vertical locations of instruments on the computed elevations, using both the single-base and two-base method of observing. Brief study of new instruments and methods of trigonometric and spirit leveling including the electronic elevation meter and radar altimeter. Determination of economic relationships of vertical control methods to mapping scale particularly with respect to photogrammetric methods.

2121. *ELEMENTS OF PHOTOGRAMMETRY.* Elective for upperclassmen and graduates. Credit three hours. Fall term. Prerequisite, 2103. Lectures, recitation, and laboratory work. A study of both principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereo-plotting instruments, parallax distortions, graphical tilt determination, trimetrogen charting, and economics. Both vertical and oblique methods are studied.

2122. *ADVANCED PHOTOGRAMMETRY.* Elective for seniors and graduates. Credit three hours. Any term. Prerequisite, 2121. Lectures, reading, and

laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. The principles of many of the most recent photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel.

2123. *SURVEYING AND MAPPING INSTRUMENTATION.* Elective. Credit three hours. Spring term. Prerequisite, 2121. Lectures and assigned reading. Independent study of some of the new developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation, optical-reading levels and transits, electronic base line measurement, precision altimeters, sonar equipment, equiangulator, odograph, photomapping device, and stereoscopic plotters such as the Multiplex, KEK, Kelsh, Mahan, and others. The course is intended to bring the student up-to-date on new instruments and methods and is revised continually to keep pace with the rapid developments in the field.

2131. *ELEMENTS OF SURVEYING.* For other than civil engineering students. Credit one hour. Either term. One 2½-hour period a week. Use of steel tape, level, and transit. Problems of particular value to students in mechanical and electrical engineering, geology, and architecture. Text: *Surveying,* Kissam.

2142. *GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH.* Either term. Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation, and photogrammetric surveying as may be arranged.

2143. *SEMINAR IN GEODESY OR PHOTOGRAMMETRY.* One to six hours credit. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

HYDRAULICS

(Including Theoretical and Experimental Hydraulics and Hydraulic Engineering)

Messrs. BOGEMA, CHRISTENSEN, JORISSEN, LYON, PRIEST, and REID.

2301. *ELEMENTARY FLUID MECHANICS.* Fifth term. Credit three hours. Three recitations a week. Prerequisite, 1152. Dynamics of fluid flow, law of continuity, pressure variation, flow analysis, viscosity effects, surface resistance and form resistance. Text: *Fluid Mechanics,* Streeter.

2302. *HYDRAULICS.* Sixth term. Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 2301. A correlation of existing hydraulic data and flow relations with the principles of fluid mechanics to provide the student with a practical means of attacking the common problems of flow of liquids. Consideration is given to such control and measuring devices as the orifice, weir, Venturi meter, and nozzle; flow in pipe systems; pressure waves; flow in open channels; turbines and centrifugal pumps.

2303. *ADVANCED HYDRAULICS.* Elective. Credit three hours. Fall term. Three lectures and recitations a week. Prerequisite, 2302 (or 2331). This course involves more detailed and extended theory and application than the first course. Problems considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, open channel flow, and hydraulic jump.

2304. *HYDRAULIC MEASUREMENTS.* Elective. Credit three hours. Fall term. One period a week in laboratory or computing room and two lecture periods. Prerequisite, 2302. Experiments involving current meters and floats in canal or river; Pitot tubes; water meters, weirs, characteristics in detail of orifices, nozzles, Venturi meters, and pipes.

2305. *HYDRODYNAMICS.* Elective. Credit three hours. Spring term. Three recitations a week. Prerequisite, 2302 (or 2331) and Differential Equations. Physical properties of fluids, equations of motion, circulation, irrotational motion, conformal transformation, laboratory methods for determining flow nets, pressure distribution on submerged surfaces, vorticity, equations of viscous flow, separation, drag, turbulence, dimensional analysis and similitude.

2306. *PUMPS AND TURBINES.* Elective. Credit three hours. Spring term. Two recitations and one laboratory or computation period a week. Prerequisite, 2302 (or 2331). Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery.

2307. *FLOW IN OPEN CHANNELS.* Elective. Credit three hours. Two lectures and one computing period a week. Prerequisite, 2302. Uniform flow, gradually varied flow, rapidly varied flow, hydraulic jump, waves, transitions, bends, obstructions, steep slopes, spillways, energy dissipation, and hydraulic models.

2308. *HYDRAULIC MODELS.* Elective. Credit three hours. Spring term. One recitation and two laboratory or computing periods a week. Prerequisite, 2302. Theory and practical use of models in designing hydraulic structures.

2331. *FLUID MECHANICS.* Required for students in mechanical and electrical engineering. Credit three hours. Either term. Three recitations a week. Prerequisite, 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible and incompressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery. Several demonstration lectures are given to illustrate fluid mechanics principles. Text: *Elementary Fluid Mechanics,* Vennard.

2342. *HYDRAULIC RESEARCH.* Elective. Either term. Prerequisite, Course 2302 or its equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is often desirable and is permissible for two students to work together on the same investigation. Written reports are required, but the text need not be typewritten in thesis style. These reports are kept by the department. In most cases it is necessary to arrange a definite schedule for work in the laboratory to avoid conflicts.

2343. *HYDRAULICS SEMINAR.* Elective. Open to specially selected seniors or graduate students. One to six hours credit. Abstraction and discussion of technical papers and publications in the hydraulic engineering field.

2403. *HYDRAULIC STRUCTURES.* Elective. Credit three hours. Spring term. Three lectures and recitation periods each week. Prerequisite, 2412. The various types of hydraulic engineering structures required for the development of water resources are presented. These include conveyance structures such as canals, pipe lines, tunnels, and penstocks; diversion structures such as low dams, movable dams, and barrages; and storage structures such as concrete, rock-fill, and earth dams. The basic considerations controlling the selection and use of each type of structure, their characteristics, design, and operation, and their limiting dimensions are given. Brief reports on typical projects are prepared from reviews of existing literature and presented in class by the students.

2404. *WATER POWER.* Elective. Credit three hours. Fall term. Two lectures and one computing period each week. Prerequisite, 2412. History of water power development; hydrologic, hydraulic, and geologic studies of water power sites; power output of streams; selection of turbines, power plant layout, and equipment; economic considerations; and preparation of engineering reports on water power development. Problems cover determination of available power, selection of

turbines, use of pondage and storage, development of load curves, and determination of annual power output.

2406. *FLOOD CONTROL.* Elective. Credit three hours. Fall term. Two lectures and one computing period each week. Prerequisite, 2412. Analysis of general flood control problems; application of flood formulas; determination of design flood criteria; comparison of flood control methods; review of typical flood control projects; study of methods for determination of flood damage; economic analysis of proposed projects; and methods of operation during flood periods. Problems include determination of design floods by unit hydrograph methods; the routing of floods down natural channels; determination of levee locations; capacity of flood channels, and amount of storage required.

2410. *EROSION AND SEDIMENTATION.* Elective. Seniors and graduates. Credit three hours. Either term. Prerequisites, 2412, Engineering Geology 113. The hydraulic engineering aspects of erosion, sediment transportation and deposition are included. The factors, such as type of soil, slope of land surface, intensity and duration of precipitation, land use, and land cover, that affect the amount of erosion; the principles governing sediment transportation, such as the quality and quantity of sediment entering the stream, and the capacity of the stream to transport such material; the methods of measuring the quantity and quality of sediment in streams and of sediment in reservoirs, the problems of sedimentation encountered in irrigation, flood control, and navigation of rivers and harbors; the characteristics of important sediment-laden streams.

2411. *RIVERS AND HARBORS.* Elective. Credit three hours. Fall term. Prerequisites, 2302 and 2412. Rivers: regimen of flow in natural streams; surface profiles for assumed steady flow; flood waves; model studies. Harbors: gravity waves; sea and shore relationships; effects of man-made changes of the shore; shore and harbor improvements, model studies.

2412. *APPLIED HYDROLOGY.* Required of all civil engineering students, seventh or eighth term. Credit three hours. Three lecture-recitation periods a week. Prerequisite, 2302. The occurrence, properties, transformations, combinations, and movements of water in the vicinity of the surface of the earth, together with the application of economic, sociologic, and fundamental engineering concepts to the control of floods, development of water power, establishment and operation of drainage districts, construction and maintenance of harbors and navigable channels, and the planning of irrigation projects.

2441. *PROJECT.* Elective. Credit three hours. Spring term. Two lectures and one computing period each week. Prerequisites, 2402, 2406, and 2412. The development of a selected site for multiple-purpose use, including coordination of available storage capacity for control of flood waters, development of water power, and release of water for navigation, water supply, or irrigation. Determination of relative benefits from each purpose and the economics of the project as a whole. Review of existing multiple-purpose developments.

2442. *HYDRAULIC ENGINEERING RESEARCH.* Elective. Graduate students. Either term. Prerequisites, 2412 and one additional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Preparation of extensive bibliography after extended search of available literature; extraction of pertinent data from all available sources; construction and operation of hydraulic laboratory models; and preparation of concise summary report covering selected investigation.

2443. *HYDRAULIC ENGINEERING SEMINAR.* Elective. Graduate students or specially selected senior students. Credit one to six hours. Either term. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the hydraulic engineering field.

SANITARY ENGINEERING

Messrs. GATES, GIFFT, and SANFORD.

2501. *MICROBIOLOGY IN ENGINEERING.* Required of all students in civil engineering. Credit three hours. Two lecture recitations and one laboratory a week. Prerequisite, Chemistry 106. Introduction to the nature, characteristics, and activities of microorganisms and their effect on man and his environment, including their roles in the transmission of disease, in the cycles of the elements of nature, in the aerobic and anaerobic decomposition of organic and inorganic material, and in industrial processes.

2502. *WATER SUPPLY AND TREATMENT.* Required of all students in civil engineering. Credit three hours. Two recitations and one computing period a week. Prerequisite, 2301. Sources of water supply, quantity available, uses, and rates of demand. Quality, examination, treatment, and purification. Collection, storage, pumping, and distribution systems. Laboratory periods will include examination and reports on water supply systems, simple design problems, and cost estimates.

2503. *SEWERAGE AND SEWAGE TREATMENT.* Required of all students in civil engineering. Elective for chemical engineering students and for others having prerequisite training. Credit three hours. Either term. Two recitations and one computing period a week. Prerequisite, 2301. The design of sanitary and storm sewers and the methods of treating sewage are considered in the recitations; in the computing period, problems are assigned dealing with design and operation and with subject matter considered in recitation and classroom work. The problems are largely of the nature of separate designs.

2504. *SANITARY BIOLOGY.* Required of graduate students who have not had 2501 or its equivalent. Credit three hours. Two lectures, one laboratory, plus special assignments. Either term. This course deals with the fundamentals and methods of microbiology with emphasis on water bacteriology and aquatic biology. Consideration is given to the nature and control of microorganisms associated with water quality and treatment and the biology of self-purification and of waste treatment processes.

2506. *ADVANCED WATER SUPPLY AND TREATMENT.* Elective for seniors and graduates. Credit three hours. Spring term. Two recitations and one computation period a week. Prerequisite, 2502. This course comprises a comprehensive study of the general principles and methods involved in furnishing safe water supplies of satisfactory quality. The topics studied include water treatment methods, including coagulation, sedimentation, aeration, slow and rapid sand filtration, taste and odor control, softening and iron removal, corrosion control, sterilization, and miscellaneous treatment methods. Also some study of design and operation of water treatment plants is included.

2507. *ADVANCED SEWAGE TREATMENT.* Elective for seniors and graduates. Credit three hours. Fall term. Two recitations and one computation period a week. Prerequisite, 2503. A comprehensive study of principles and methods involved in the design, construction, and operation of sewage treatment works, including reference to existing typical plants. In general, the study includes the disposal of sewage by dilution; stream pollution and self-purification; sewage treatment methods, including preparatory devices, sedimentation, chemical precipitation, intermittent sand and trickling filters, activated sludge, sludge digestion, sludge dewatering and incineration, and miscellaneous treatment methods.

2508. *INDUSTRIAL WASTES.* Elective for seniors and graduates in civil engineering and for chemical engineers. Credit three hours. Fall term. Three lectures or recitations a week. Prerequisite, 2503. The treatment of municipal and industrial wastes such as garbage, and the wastes from tanneries, packing houses, mines,

canning factories, textile mills, paper and pulp mills, creameries, cheese factories, condenseries, breweries, sugar refineries, etc. Flow or process charts are used to show the general character of the waste, and methods of treatment applicable are considered. Special attention is given to experimental studies of waste treatment, and to plant-scale treatment. Numerous references, bulletins, reports.

2509. *PUBLIC HEALTH.* Elective for advanced and graduate students in civil engineering and students outside the School by permission of the instructor. Credit three hours. Spring term. Three recitations or lectures a week. M W F 9. A general course outlining basic principles in transmission of disease and communicable disease control; organization and functions of federal, state, and local health departments; standards of environmental sanitation including water supply, waste disposal, milk, restaurant and school sanitation; insect and rodent control; industrial hygiene; vital statistics. Content of course adjusted to the needs of the students enrolled in order to demonstrate the responsibility of the individuals and their professions for maintaining the public health.

2510. *ENVIRONMENTAL SANITATION.* Elective for advanced and graduate students. Credit three hours. Fall term. Lectures, reports, and recitations. Three periods a week. A course dealing with public health engineering practice in the control of problems of environmental sanitation. Emphasis is on the engineering aspect of industrial hygiene, milk, and food sanitation, swimming pool design, and housing.

2511. *SANITARY ENGINEERING LABORATORY.* Credit three hours. One lecture-discussion and two laboratory periods a week. Prerequisites, 2502, 2503. The application of physical, chemical and bacteriological principles, methods and procedures to the analysis and treatment of water, sewage, and industrial wastes. Laboratory scale study of water and sewage treatment processes; interpretation and application of these laboratory data to the design and operation of treatment processes and units.

2531. *STREAM POLLUTION.* Elective. Not open to students taking 2502 and 2503. For advanced and graduate students outside the School. Credit three hours. Three recitations or lectures a week. M W F 9. Fall term. This course deals with the pollution of surface, ground and tidal waters and with the economic and legal problems connected with its control. Consideration is given to sources and types of pollution, forces of self-purification, permissible pollution loading, pollution surveys, water quality standards, classification of waters, and water, sewage and industrial wastes treatment processes.

2541. *PROJECT.* Elective. Credit three hours. Either term. This course should be preceded by 2502 and 2503 or equivalent courses. The purpose of the course is to teach methods of determining the capacity, basis of design, computations, sketches, and general plans involved in the design of sewerage, industrial waste, and water treatment works. Problems may be elected such as the design of a separate or combined sewerage system, an intercepting sewer, a municipal or an institutional sewage treatment plant, a plant for the treatment or disposal of an industrial waste, or a plant for the treatment of an industrial, institutional, or municipal water supply.

2542. *SANITARY ENGINEERING RESEARCH.* Either term. Prerequisites for work in this field will depend upon the particular problem to be pursued, but in general should include work in water analysis, bacteriology, and courses in hydraulics and sanitary engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, prerequisites, and other questions relating to contemplated research in this field will be arranged by conference.

2543. *SANITARY ENGINEERING SEMINAR.* Elective. Open to specially selected seniors or graduate students. One to six hours credit. Abstraction and discussion of technical papers and publications in the sanitary field.

TRANSPORTATION ENGINEERING

Messrs. BELCHER, LEWIS, and PERRY.

2602. *TRANSPORTATION.* Required of all civil engineering students. Elective for seniors and graduates. Credit three hours. Lectures and recitations three hours a week. A course covering travel and transport agencies with special reference to their facilities, ownership, financing, regulation, and coordination. A brief review of the development of transportation throughout the world is used as a background for an intensive study of the present situation in the various countries and comparison of the policies and practices in use. Particular attention is given to the various proposals designed to promote more efficient use of the various transportation agencies in the United States by better coordination, pooling of facilities, etc., and economic studies are made of some of the new projects which are under discussion.

2603. *RAILROAD MAINTENANCE OF WAY.* Elective. Seniors and graduates. Credit three hours. Fall term. Lectures and recitations three hours a week. Prerequisite 2113. The subjects treated are track materials (with special reference to the section, method of manufacture, and composition of steel rails, to the economics of tie preservation and the use of metal ties, and to the effect of quality of ballast upon maintenance); machine and other methods of grading for second track; drainage; track laying by both machine and hand methods, ballasting and bringing new track to line and grade; turnouts and switches; derailing switches; sidetracks and yard tracks; sorting and terminal yards; track maintenance; track tools, work trains; action of car wheels on curves; widening of gage; double tracking; separation of grades and improvement in grades and alignment. Text: *Railway Track and Maintenance,* Tratman.

2604. *RAILROAD OPERATION AND MANAGEMENT.* Elective. Seniors and graduates. Credit three hours. Spring term. Lectures and recitations three hours a week. Prerequisite, 2113. Under organization, the following subjects are treated: general principles underlying organization and the effect of each on efficiency; principal departments of railway service with a brief outline of the work of each; departmental and divisional systems of organization, with examples from various roads and discussion of adaptability of each. The duties of officers and the work of the different departments are taken up in considerable detail. The most important laws affecting railroads are given in discussing the work of the legal department. Freight traffic, freight houses, classification yard, car service rules, accounting, etc., are among the topics considered under operation. Signaling and interlocking and train rules are also considered.

2610. *HIGHWAY ENGINEERING.* Required of all civil engineering students. Credit three hours. Two lectures, one computing period or field assignment each week. Prerequisite, 2113, and preceded by or taken concurrently with 2725. Design, construction, and maintenance of highways and city streets. Location and alignment (aerial photographic methods included), width, capacity, and geometrical design based on traffic demands. Drainage, soils, stabilization, aggregates. Bituminous materials. Structures, traffic control, landscaping. Economics and administration. Construction methods and equipment for grading and paving of low cost, flexible, and rigid pavements. Analysis and correction of characteristic pavement failures.

2612. *HIGHWAY LABORATORY—BITUMINOUS.* Elective. Seniors and graduates. Credit three hours. Spring term. Two laboratory periods a week. Prerequisite, 2610 or may be taken concurrently with 2610. Nonbituminous and bituminous materials are tested. Subgrade soils are sampled and their properties examined; subgrade stabilization admixtures are also tested and studied. Bituminous mixtures are designed, and their properties examined.

2613. *HIGHWAY LABORATORY—STABILIZATION.* Elective. Seniors and graduates. Credit three hours. Fall term. Two laboratory periods a week. Prerequisites, 2725 and 2610, or may be taken concurrently with 2610. Nonbituminous and bituminous materials are tested and their characteristics studied. Soils are sampled and examined, and investigations made of the behavior of mixtures of soils with bituminous and nonbituminous materials. Special investigations and tests are made to determine the properties of various combinations of materials and the effects of modifications in design.

2614. *ADVANCED HIGHWAY ENGINEERNG.* Elective. Seniors and graduates. Credit three hours. Spring term. Prerequisite, 2610. *Part I.* Soils and subgrades. Surveying sampling compaction, and stabilization practices. Special problems in excavation. *Part II.* Design and construction of base and surface courses for flexible pavements. *Part III.* Design and construction of rigid pavements. *Part IV.* Highway planning. Urban route selection, geometrical design; design of regional systems of highways, freeways, and parkways.

2617. *AIRPORT ENGINEERING.* Elective. Seniors and graduate students. Credit three hours. Fall term. Two recitations and one computing period a week. Prerequisites, 2610 and 2725. The location, design, construction, and maintenance of airports.

2618. *LOW-COST ROADS.* Elective. Seniors and graduate students. Credit three hours. Either term. Prerequisite, 2610 or its equivalent. Study of economic importance of routes and selection of (farm-to-market) roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials; drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads.

2620. *TRAFFIC ENGINEERING.* Elective. Credit three hours. Three recitations a week. Prerequisite, 2610. City and highway traffic surveys. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control and routing. Signs, signals, and markings. Regulation; truck and bus units as traffic elements. Urban traffic consideration in city planning. Driver reactions and habit patterns; design of safety features and effectiveness of signs. Also air traffic for those specializing in airports.

2621. *ENGINEERING INTERPRETATION OF AERIAL PHOTOGRAPHS.* Elective. Credit three hours. Two recitations and one computing period a week. Prerequisites, 2610, 2725. A study of the soil and rock areas of the United States and the patterns that they present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Extensive field training in selected test areas. Special emphasis is placed on the interpretation of engineering information dealing with construction, excavation, clearing, water supply, drainage requirements, and foundation problems.

2641. *PROJECT, TRANSPORTATION ENGINEERING.* Elective. Credit three hours. Either term. Projects in the various fields of transportation, advanced aerial photographic studies, and traffic engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. *TRANSPORTATION ENGINEERING RESEARCH.*

(a) *RAILROAD ENGINEERING.* Either term. Special problems in the economics of location, construction, maintenance, and operation of railroads, com-

parison of transportation agencies, traffic studies, and economics of various systems of transport.

(b) *HIGHWAY ENGINEERING.* Either term. Prerequisites, 2610 and 2614. Studies of traffic and traffic regulation and legislation may be made. The field of economics of highway engineering offers a wide variety of problems. Laboratory investigations of subgrade soil, subgrade stabilization, and the effects of modifications in design of bituminous and nonbituminous mixtures provide a wide range of topics for research.

2643. *TRANSPORTATION ENGINEERING SEMINAR.* Elective. Open to selected seniors or graduate students. Credit one to six hours. Either term. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

STRUCTURAL ENGINEERING

Messrs. BIJLAARD, FISHER, GURALNICK, HOUGH, MASON, McGUIRE, WINTER, and ZUK.

2701. *ELEMENTARY STRUCTURAL ANALYSIS.* Required of all civil engineering students. Credit three hours. Two recitations and one problem period a week. Prerequisite, 1153. A first course in structural theory. Determination of reactions and internal forces and moments in beams, girders, trusses, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods and of influence lines.

2702. *STEEL AND TIMBER STRUCTURES.* Required of all civil engineering students. Credit three hours. Three problem periods a week. Prerequisite, 2701. Design of structural members and connections. Detailing, fabrication, and erection procedures. Partial design of timber roof truss, riveted and welded steel mill building bent, plate girder railroad bridge, light gage steel structures. Development and criticism of current design specifications.

2704. *STATICALLY INDETERMINATE STRUCTURES.* Required of all civil engineering students. Credit three hours. Three recitation periods a week. Prerequisites, 2701, 2702. Common methods of structural analysis applied to continuous beams, rigid frames, indeterminate trusses. Deflection of trusses. Use of influence lines in design.

2706. *ADVANCED STEEL DESIGN.* Elective for seniors and graduate students. Credit three hours. Three two-hour periods. Prerequisites, 2702 and 2704. Critical discussion of loading conditions for buildings and bridges. Study of steel framing systems in current use. Problems and the analysis and design of (a) a modern commercial or industrial steel structure, (b) a truss bridge, (c) a tower or other special steel structure.

2709. *ADVANCED STRUCTURAL ANALYSIS.* Elective for graduate students. Advanced undergraduate students by special permission. Credit three hours. Three periods a week. Prerequisite, 2704 or satisfactory examination. Review and critical comparison of fundamental methods for the solution of statically indeterminate structures and extension to more involved problems. Column analogy, members of variable cross-section, secondary stresses, wind stresses, Vierendeel trusses. Use of influence lines, numerical methods and model analysis for design. Design problems. Text: *Statically Indeterminate Structures,* Maugh.

2710. *STRENGTH OF STRUCTURES.* Elective for graduate students and advanced undergraduate students. Prerequisite, 2704 (can be taken concurrently). Credit three hours. Three recitations a week. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, buckling, and impact. Structural ma-

terials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Plastic or ultimate design of steel and reinforced concrete structures. Critical discussion of current design specifications.

2711. *BUCKLING OF STRUCTURES.* Elective for graduate students. Advanced undergraduate students by special permission. Prerequisites, 2710 and 1145 or equivalent. Credit three hours. Three recitations a week. Analysis and design involving elastic stability. Determination of buckling loads and maximum stresses of columns with and without initial crookedness and eccentricity. Solid and open web columns with variable cross-section. Beam columns. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin, compressed plates. Design of thin-walled steel structures. Critical discussion of current design specifications.

2712. *TANKS, BINS, AND ROOFS.* Elective for graduate students. Advanced undergraduate students by special permission. Prerequisites, 2704 and 1145 or equivalent. Credit three hours. Three recitations a week. Analysis and design of domes, tanks, reservoirs, bunkers, bins, and long-span roofs in reinforced concrete (plain and prestressed). Methods of analysis include theory of plates and shells, advanced beam theory, hipped plate construction.

2713. *STRUCTURAL DESIGN.* Required of all civil engineering students. Credit three hours. Three problem periods a week. Prerequisites, 2704, 2720, 2715, 2702. Mechanical properties of steels and nonferrous metals as related to structural design. Strain hardening, stress concentration, fatigue. Technology, properties, and effects of welding. Planning and design of representative portions of complete structural projects (framed buildings, bridges, other structures). Integrated use of basic design procedures presented in preceding courses.

2715. *REINFORCED CONCRETE DESIGN.* Required of all civil engineering students. Credit three hours. Either term. One lecture and two problem periods a week. Prerequisite, 2704 (can be taken concurrently). A first course in reinforced concrete. Elementary theory of reinforced concrete is applied to rectangular slabs, T-beams, beams reinforced for compression, columns, and footings. Shear, diagonal tension, and direct stress combined with flexure are treated. Several design reports are required which include reinforcement drawings, schedules, and formwork. Text: *Design of Concrete Structures,* Urquhart and O'Rourke.

2716. *ADVANCED REINFORCED CONCRETE DESIGN.* Elective for seniors and graduate students. Credit three hours. Three two-hour periods a week. Prerequisites, 2715 and 2704 (or concurrently). Design problems in combined footings, counterfort retaining wall, flat-slab construction, floor systems, highway bridge, single-span arch structures. Critical review of design specifications and recent research.

2717. *BRIDGE DESIGN.* Elective for graduate students and qualified seniors. Credit three hours. Prerequisites, 2702, 2715, 2704. Design of more complex types of steel and concrete bridges, such as continuous truss, multiple box culvert, rigid frame, arch. Basic planning of bridge project and study of problems common to all types of bridges, including substructures. Attention is given to traffic, hydraulic, and economic requirements, and use of field data, preliminary surveys, and model studies.

2720. *FOUNDATIONS.* Required of all civil engineering students. Credit three hours. Two lectures and one computing period a week. Prerequisites, 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems. Text: *Substructure Analysis and Design,* Anderson.

2725. *ELEMENTS OF SOILS ENGINEERING.* Required of all students in civil engineering. Credit three hours. Either term. Two lectures and one laboratory period a week. Prerequisites, Geology 113, 1153, 2301. The elements of the formation and composition of soil, its fundamental properties, and its behavior as an engineering material. Instruction in principles of soil identification and classification, basic terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with applications to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Theory of lateral earth pressure. Discussion of methods and equipment for soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluations and use of data.

2726. *SOILS ENGINEERING THEORY.* Elective for seniors and graduate students. Credit three hours. Fall term. Three lectures a week. Prerequisite, 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which affect their application. Methods for determining the distribution of stresses induced in semi-infinite soil masses by surface and body forces, variation of stress at a point, and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of the amount and rate of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate of seepage and effect of seepage on stability of structures. Lateral earth pressure theory.

2727. *APPLIED SOILS ENGINEERING.* Elective for seniors and graduate students. Credit three hours. Spring term. Two lectures and one long period a week. Prerequisite, 2726. Application of soils engineering theory to problems. Planning and conduct of subsurface investigations for various types of work, determination of significant physical and chemical soil characteristics by test or other means, including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage or other service requirements, methods for inspection and control of earthworks construction, selection and placement of materials, compaction and stabilization.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING.* Elective for students not in civil engineering. Credit two hours. One lecture and one computing period a week. Analysis and design of structural members and connections: steel, timber, reinforced concrete, simple foundations. Text: *Elementary Structures,* Cissel.

2741. *PROJECT.* Elective. Either term. Prerequisites, 2702, 2703, and 2715. The student may select a problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports.

2742. *STRUCTURAL ENGINEERING RESEARCH.* Any term. Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2743. *STRUCTURAL ENGINEERING SEMINAR.* Elective. One to six hours credit. Open to specially selected seniors or graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

SPECIAL AND GRADUATE COURSES

2801. *THESIS.* Elective. Seniors. Credit three or more hours. Either or both terms. The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

SPECIAL NOTE

Individual courses may be arranged to suit the requirements of graduate students. These special courses are intended to be pursued under the immediate direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

ADMINISTRATIVE ENGINEERING

Messrs. CRANDALL, GEBHARD, and THATCHER.

2901. *CONSTRUCTION METHODS.* Required of all civil engineering students. Credit three hours. Either term. Lectures and recitations three hours a week. A fundamental course designed to acquaint the student with the financial and economic principles underlying construction enterprises, both public and private, and with the agencies—money, men, materials, and machines—utilized in carrying out construction projects, and their correlation and control. Methods and processes of construction with special attention to the equipment required and its adaptability to various kinds of work. Problems and reports on references to periodical literature are required of all students. Textbook: *Construction Planning and Plant,* Ackerman and Locher.

2902. *ENGINEERING LAW.* Required in fourth year. Credit three hours. Either term. Lectures and recitations three hours a week. An introductory course in the laws of contract, tort, agency, real property, water rights, form of business organization, sales, and negotiable instruments; special emphasis on contract documents required on construction work; collateral topics such as workmen's compensation, mechanics' liens, bankruptcy, wills, western water law, and patent law are also included. Text: *Contracts in Engineering,* Tucker.

2903. *ECONOMICS OF ENGINEERING.* Required in the fourth year. Credit three hours. Either term. Lectures and recitations three hours a week. Prerequisites, 2901 and 3231. The economic aspects of engineering and the application of principles of management to the work of the engineer; economic selection of materials, equipment, and structures; studies for the replacement of existing units; plant layouts; public works economy; the technique of estimating quantities and costs for various types of engineering projects. Textbooks: *Principles of Engineering Economy,* Grant; *Construction Estimates and Costs,* Pulver.

2904. *PUBLIC ADMINISTRATION.* Required in fifth year. Credit three hours. Either term. Lectures and recitations three hours a week. A course to acquaint the prospective city engineer, superintendent of public works, city manager, or executive engineer in charge of various government bureaus or departments with the administrative problems he must face in addition to strictly technical engineering duties. Budgets, controlling legislation, civil service regulations, city planning, and public administration practices are included. Text: *Municipal Affairs,* Steele.

2905. *VALUATION ENGINEERING.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequi-

sites, Construction Methods, Accounting, Engineering Law, or concurrently therewith. Theory and practice of valuation for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, securities, bank loans and mortgages, insurance, uniform systems of accounting, and improved management.

2906. *ADVANCED ENGINEERING LAW.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequisite, 2902. An extension, by the use of case material, of some of the legal principles covered in 2902, particularly the laws applying to the various phases of construction contracts and employer-employee relationships; additional fields included are suretyship, insurance, bailments, and conditional sales. Text: *Law for Engineers and Architects,* Simpson and Dillavou.

2907. *CONSTRUCTION MANAGEMENT.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequisites, Construction Methods, Economics of Engineering, Accounting. Planning and operation of construction projects by the civil engineer, including coordinated organization of men and machines, scheduling and estimating, purchasing, selection and training of men, operation and maintenance of equipment, cost keeping and reports, pay systems, accident prevention, and other related factors.

2941. *PROJECT. ADMINISTRATIVE ENGINEERING.* Elective. Credit three hours. Either term. The student may select a project involving the design, planning, and construction of any private or public engineering work which is of particular interest to him, with special emphasis upon the legal, financial, and management aspects.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH.* Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR.* Elective. One to six hours credit. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the field of administrative engineering.

MECHANICAL ENGINEERING

NUMBERING SYSTEM IN THE SCHOOL OF MECHANICAL ENGINEERING. The first digit (3) of the number designates the School of Mechanical Engineering, the second digit indicates the department in the school, and the third and fourth digits constitute the course numbers within the department. The courses in aeronautical engineering fall under the Graduate School of Aeronautical Engineering. Department numbers are: 0, General; 1, Engineering Drawing; 2, Industrial and Engineering Administration; 3, Machine Design; 4, Materials Processing; 5, Heat-Power Engineering; 7, Automotive Engineering. The following are the numbers of the service courses: Mechanics, 1100 and up; Engineering Materials, 1200 and up. The courses in aeronautical engineering have 7 as the initial digit.

The courses in mechanical engineering are listed under the following headings: Automotive Engineering, Drawing and Descriptive Geometry, Heat-Power Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing.

Required courses in the mechanical engineering curricula given outside the College of Engineering:

Chemistry 105, 106. General Chemistry (p. 119)
Chemistry 301. Introduction to Organic Chemistry (p. 119)
Chemistry 402. Introduction to Physical Chemistry (p. 120)

Economics 107. Introduction to Economics (p. 121)
English 111, 112. Introductory Course (p. 121)
History 165, 166. Science in Western Civilization (p. 121)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (p. 122)
Physics 115. Mechanics (p. 122)
Physics 116. Wave Motion, Sound, and Heat (p. 123)
Physics 117. Electricity and Magnetism (p. 123)
Physics 118. Physical Electronics and Optics (p. 123)
Psychology 101. Psychology for Engineering Students (p. 124)
Public Speaking 101 (p. 124)

Required courses in mechanics of engineering, strength of materials, and engineering materials are described on pages 69-74.

GENERAL

3041. *NONRESIDENT LECTURES.* Terms 9 and 10. Required. Total credit one hour for both terms. Both fall and spring terms. One lecture each week.

The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life.

3051. *A.S.M.E. STUDENT BRANCH.* Credit one hour. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective hour may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, West Sibley Basement, or to the Honorary Chairman of the Student Branch, E. B. WATSON, Associate Professor of Mechanical Engineering.

DRAWING AND DESCRIPTIVE GEOMETRY

Messrs. BAIRD, CLEARY, MORDOFF, and SIEGFRIED.

3111. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit three hours. Fall term. One hour of freehand drawing and two laboratory periods of mechanical drawing and descriptive geometry a week. Freehand drawing includes studies in freehand sketching, parallel and perspective projection, esthetics in engineering, and applications in creative sketching. Mechanical drawing and descriptive geometry include studies in the prerequisites of mechanical drafting; lettering, delineation and descriptive geometric anatomy.

3112. *BASIC MECHANICAL DRAFTING.* Credit three hours. Spring term. One hour of freehand drawing and two laboratory periods of mechanical drafting a week. Prerequisite, 3111. Continuation of the freehand drawing content of 3111. Mechanical drafting content includes basic layout and detail practice applied to the creation, expression, and interpretation of specifications for mechanical anatomy.

3114. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit two hours. Fall term. One recitation and one laboratory period a week. Content is similar to 3111, but it is abbreviated and freehand drawing is omitted.

3115. *BASIC MECHANICAL DRAFTING.* Credit two hours. Spring term. One recitation and one laboratory period a week. Prerequisite, 3114. Content is similar to 3112, but it is abbreviated and freehand drawing is omitted.

3116. *CREATIVE SKETCHING.* Elective. Either term. Credit two hours. Two laboratory periods a week. A course designed to train the eye to see form and proportion with greater accuracy, to stimulate the processes of creative thinking through the acquiring of facility with the pencil, and to acquaint the student with the interdependence of technology and today's forms.

3117. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit two hours. Fall term. Two laboratory periods a week. Same as 3111 except freehand drawing is omitted.

3118. *BASIC MECHANICAL DRAFTING.* Credit two hours. Spring term. Two laboratory periods a week. Prerequisite, 3117. Same as 3112 except freehand drawing is omitted.

3131. *MECHANICAL DRAFTING RESEARCH AND DEVELOPMENT.* Credit to depend upon hours of actual work. Elective any term for limited number of qualified seniors and graduates. Special problems and investigations in the subject matter, tools, materials, and processes of mechanical drafting.

3198, 3199. *PROJECT.* Total credit six hours. These course numbers are assigned to cover work done during the last undergraduate year on a project in the fields of drawing and industrial design. The credit hours given for each course will depend upon the amount and quality of the work done each semester.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLEN, GAVETT, HANSELMAN, KRICK, LOBERG, McGARRAH, PAJKOWSKI, SAMPSON, SAUNDERS, SCHULTZ.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* Credit three hours. Two recitations and one computing period a week. A basic course in the principles of industrial accounting including controlling accounts, special journals and ledgers, voucher system, and manufacturing cost systems.

3232. *PERSONNEL MANAGEMENT.* Credit three hours. Two lectures and one recitation a week. Prerequisites, 3235 and 3241 or consent of the instructor, junior standing. This course involves an investigation and evaluation of the techniques used in the handling of personnel functions. The major topics are selection and evaluation of the employee, job analysis, job rating, training, and motivation as well as the organization of the personnel department and its relationship to other departments in an industrial organization.

3233. *REPORT WRITING.* Credit one hour. One recitation a week. Elective for engineering students only. The organization of engineering material into concise written form. This course covers the preparation of engineering reports including organization, description of apparatus and procedures, the graphical presentation and summary of results. It will also include a discussion of business letters of special interest to engineers and written specifications.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT.* Credit three hours. Three lectures a week. An introductory course in the field of industrial management. The industrial revolution, the principles of mass production, types of business enterprises, and the location and growth of industry. The organization of the plant facilities and the plant personnel with special emphasis on the layout of the plant, types of organizational control, production control, personnel functions, motion and time study, and wage payment systems. This course differs from 3236 (see below) in that it includes a discussion of types of business enterprises, the major functions of the personnel department, and covers wage systems in more detail. It does not go into as much detail on production control and does not include any discussion of cost and budgeting problems.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION.* Credit three hours. Three lectures a week. An introductory course in the field of industrial management covering organizational structure, including types of organization and a discussion of the organization of specific companies; production control, including layout, materials handling, planning, scheduling, routing, dispatching, and inspection; worker productivity, including motion study, time study, job evaluation and incentive wage plans; and a brief discussion of problems in engineering economy. This course is offered specifically for the School of Industrial and Labor Relations students. Engineers may not register for this course. Other students may register only by permission of the instructor.

3241. *INDUSTRIAL STATISTICS.* Credit three hours. Two recitations and one computing period a week. Prerequisite, Calculus. The industrial applications of probability theory and statistical analysis with special emphasis on inspection and controlling the quality of industrial products. Engineering applications of significance tests, analysis of various regression and correlation and contingency tables. Index numbers, time series are also discussed.

3242. *STATISTICAL QUALITY CONTROL.* Credit three hours. Three recitations and one computing period a week. Prerequisite, 3241 or equivalent. Basic statistical applications in the field of industrial production, inspection, and experimentation. Various sampling, control, and inspection problems, with special reference to practical applications. Underlying theory, assumptions, and limitations. Problems of organization and administration are also discussed.

3247. *PRINCIPLES OF COST CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3231 or equivalent. Cost collection for production order and continuous process industrial operations. The purposes of cost accounting, the effect of the type of organization of the enterprise, and the conception of the basic principles of cost control are stressed. Budgets and standards as a goal for adequate cost control.

3250. *INDUSTRIAL ACCOUNTING AND COST CONTROL.* Credit four hours. Three lectures and two computing periods a week are scheduled, but a class will meet only four times a week. Prerequisite, 3235. A basic course in modern industrial accounting theory including detailed study of cost collection systems with emphasis on principles of control. Special journals and ledgers, controlling accounts, voucher system, production order and process type systems are studied. Standard costs and budgets are also discussed. Courses 3231 and 3247 fulfill the requirement for this course.

3253. *CHEMICAL ENGINEERING COST ACCOUNTING.* Credit three hours. Two recitations and one computing period a week. Basic accounting and cost accounting are studied. Emphasis on the cost accounting and cost analysis which applies to the chemical industry. Standards, budgetary control, profit analysis, and statement analysis are discussed briefly to emphasize the necessity of complete cost control.

3254. *STANDARD COSTS AND MANAGEMENT CONTROL.* Credit three hours. One lecture and two computing periods a week. Prerequisites, 3250 and 3263 or 3261. A comprehensive study of profit analysis, static budgets, standard costs, flexible budgets, and other cost analyses as applied to production and sales. The establishment of, the organization for, and the control through standards for material, labor, overhead are thoroughly studied. Presentation of the cost information for use by management is emphasized.

3261. *INDUSTRIAL ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisites, 3250, 3404 or equivalent, or by consent of the instructor. A course that integrates the several fields of engineering in which a knowledge of machine design, materials, and production tools and proc-

esses are utilized to determine correct manufacturing methods and their proper sequence. The laboratory work consists of related problems covering such topics as methods engineering, principles of engineering economy, including economic lot size, materials handling, plant layout, production control, and the production analysis of various manufactured products.

3262. *METHODS ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3235 or 3236. A study of the factors influencing the productivity and economy of industrial operations and related jobs. This includes the charting and analysis of problems of work flow in industry; the coordination of man time and machine time in manufacturing operations; the principles of motion economy and micromotion analysis; the theory and practice of time study for setting operational standards through watch studies, standard data, and elemental motion standards; and incentive systems for direct and indirect labor jobs. Emphasis is placed on personnel and human relations problems associated with methods improvements and incentive systems.

3263. *PRODUCTION ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisites, 3262, 3250, 3404, or consent of the instructor. This course integrates the engineering and economic principles governing production. The student will analyze various manufactured products as to material; methods; operations; machine selections; tool, jig, and fixture requirements; operational times; and materials handling techniques based on the principles of engineering economy.

3264. *PRODUCTION ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3263. A continuation of 3263. The computations and designs made in 3263 will be used as a basis for further integration of production and engineering. The student will compute floor space requirements resulting in a complete plant layout of both productive and service departments. After this, the basic problems of production planning, production control, and cost control concerned with the layout will be discussed.

3265. *PRODUCTION CONTROL.* Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 3264. A detailed study of the principles and methods of production control, including job estimating; planning, routing, scheduling, and dispatching of manufacturing operations; inspection and quality control; storekeeping; machine records and machine loading; tool crib operation; forms design; Gantt charts and the use of control boards.

3266. *ADVANCED METHODS ENGINEERING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3262 and 3241 or consent of instructor. A critical appraisal of methods engineering practices and principles including ways to maintain time standards; examination of several time study departments; improvement of stopwatch time study; derivation of standard data; theory of predetermined elemental motion time systems; and detailed examination of one such technique: methods-time measurement. Also included are ratio delay studies; psychological factors in machine and job design; and improvement of the variable tasks. Several weeks are spent on projects in areas of special interest to the individual student.

3270. *INDUSTRIAL MARKETING.* Credit three hours. Three recitations a week. Prerequisites, 3250, 3241. A study of industrial marketing as related to product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems are also covered.

3271. *INDUSTRIAL MARKETING RESEARCH.* Credit three hours. Prerequisite, 3270. Techniques of market research applied to specific problems related to industrial goods.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit as arranged. Offered to qualified students individually or in small groups. Involves the study, under direction, of special problems in the field of industrial and engineering administration.

3298, 3299. *PROJECT.* Total credit six hours. These course numbers are assigned to cover work done during the last undergraduate year on a project in the field of industrial and engineering administration. The credit hours given for each course will depend upon the amount and quality of the work done each semester.

MACHINE DESIGN

Messrs. BURR, DuBOIS, HAMILTON, MABIE, NEEF, OCVIRK, PHELAN, and WEHE.

3351. *MECHANISM.* Credit three hours. Two recitations and one design-room period a week. Prerequisites, 3112, 1151. A study of displacements, linkages, cams, gears, belts, and trains of mechanism.

3352. *DYNAMICS OF MACHINERY.* Credit three hours. Two recitations and one design-room period a week. Prerequisites, 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of statics and inertia forces in mechanism; engine force analysis, flywheels, and balancing.

3353. *DESIGN OF MACHINE MEMBERS.* Credit three hours. One lecture and two design-room periods a week. Prerequisite, 3351, and prerequisite or parallel, 1154, and 1231. Application of mechanics, kinematics, materials, and processes to the design and selection of machine members such as fastenings, links, springs, translation screws, belts, wire-rope, chains, couplings, clutches, brakes, gears, shafts, and bearings.

3354. *DESIGN OF MACHINES.* Credit three hours. For students in Option A. One lecture and two design-room periods a week. Prerequisites, 3353 and 3404, and prerequisite or parallel, 6113. Application of mechanics, kinematics, materials, and processes to the design of complete machines and the modification of existing machines. Computations and layout drawings as required.

3356. *DESIGN OF MACHINES.* Credit three hours. For students in Option B. One lecture and two design periods a week. Prerequisites, 3353 and 3404, and prerequisite or parallel, 6113. Similar to 3354, but including the design or modification of production machines and the design of jigs and fixtures.

3361. *ADVANCED MACHINE ANALYSIS.* Credit three hours. Three lectures a week. Prerequisite, 3353. Extended analyses of mechanisms and machinery members such as brakes and bearings. Problems in lubrication, impact, creep, thermal stress, residual stress, and graphical determination of shaft deflection.

3366. *ADVANCED KINEMATICS.* Credit three hours. Two lecture-discussion periods and one design period a week. Prerequisite, 3352. Advanced graphical and semi-graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and unique linkages. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS.* Credit three hours. Two lectures and one experimental laboratory or computation period a week. Prerequisites, 1155, 3352, 3353. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounts, damping devices, critical speeds, inherent-balance, self-induced vibrations, and analyses in Fourier's series.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit arranged. Each term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis or experi-

mental investigation of a machine or component of a machine, or studies in a special field of machine design.

3372. *MACHINE DESIGN LABORATORY.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3353. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, characteristics of wear and lubrication, and development techniques are studied as applied to machine design problems.

3373. *CREATIVE DESIGN.* Credit two hours. Two design periods a week. Prerequisite, 3354 or 3356. Layout design emphasizing the development of improved designs by successive sketches. Use of simple rules to stimulate ideas.

3375. *MACHINERY SURVEY.* Credit three hours. Two lectures and one laboratory period for field trips a week. Prerequisite, 3353. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment. Recommended as a Term 8 elective for students considering a project in machine design.

3377. *AUTOMOTIVE ENGINEERING.* Credit three hours. Three lecture-recitations per week. Prerequisite, 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, relative to its performance. Stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability are considered. Recommended together with Course 3581 for a study of automotive engineering.

3398, 3399. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of machine design. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

MATERIALS PROCESSING

Messr. GEER and HENRIKSEN.

3402. *MACHINE TOOLS.* Credit two hours. One lecture and one laboratory period a week. Demonstrations, discussion, and operation of basic machine tools and their accessories. Demonstrations of the common type production machine tools and accessories.

3403. *FUNDAMENTALS OF MACHINE TOOLS.* Credit one hour. One laboratory period a week. Demonstrations and operation of the basic machine tools and their accessories. Small tools and their applications.

3404. *PRODUCTION MACHINE TOOLS.* Credit two hours. One lecture and one laboratory period a week. Prerequisites, 3403, 6110. Investigations of some general principles of machine tools, and a study of machine tools and their accessories for volume production, including automatic operation. Jigs and fixtures and advanced tooling techniques, such as for turret lathes, screw machines, and for thread and gear cutting, are discussed and demonstrated.

3405. *GAGE LABORATORY.* Credit one hour. One laboratory period a week. Must be taken with or after 3404. A study of measuring instruments for the control of size, form, and alignment of commercial goods and tools, including gages. Standard techniques of Ordnance, A.S.A., and others are demonstrated and applied in project inspections. Individual experience is acquired in the operation of gaging equipment.

3406. *FUNDAMENTALS OF MATERIALS PROCESSING.* Credit two hours. One lecture and one laboratory period a week. Basic machine tools, their acces-

sories and operation. Small tools and their applications. Workshop measuring methods. Industrial woodworking.

3407. *ADVANCED MATERIALS PROCESSING.* Work and credits as arranged with Mr. GEER and Mr. HENRIKSEN.

3411. *CUTTING TOOLS.* Credit three hours. Two lecture periods and one laboratory period a week. Prerequisites, 3403 or equivalent; desirable, 6110 or 1221 or equivalent. The action of the cutting tool. Chip formation and built-up edge. Grain distortion, work hardening and surface stresses. Chip pressure and its measurement. Tool wear and tool life, Woxen's tool-life equation, Ernst-Merchant's force-diagram. Cutting fluids, their performance and application. Machinability of metals. Principal features of cutting tools; angles, nose radii, chip breakers, shear cutting, vibration and chatter. Current types of single-point and multiple cutting tools. Tool grinding and maintenance.

3412. *MACHINE TOOL OPERATIONS.* Elective for undergraduates and graduate students. Credit three hours. Prerequisite, 3404. One lecture period and two laboratory periods a week. Principal production methods in machine shops. Raw materials and their preparation for production. Work- and tool-holding methods and devices, their relative properties and applications. Sequence of operations, the building up of accuracy. Principal features of conventional machining methods as related to planning, i.e., relative location of work-holding parts, and cutting tools. Bench work as applied to manufacturing methods. Tool layout for machine tools; some special methods: thread and gear manufacturing, tool room methods. High precision work. Chip disposal and shop maintenance.

3413. *MACHINE TOOLS.* Credit three hours. One lecture period and two laboratory periods a week. Prerequisite, 3351 or equivalent. Classification of machine tools, dimensional capacities, current sizes, and some exceptions from established practice. General practice for machine tool speeds and feeds, the arithmetical and the geometrical progression, limitations thereof. Mechanical, hydraulic, and electrical drives for machine tools; performance, efficiency and fields of application. Problems of strength and rigidity in machine tools. Prevention of vibration and chatter. Machine tool slides and ways. Some principal elements of machine tools. Machine tool lubrication, testing, and manufacturing methods. Present trend in development. Obsolescence and modernization, care and maintenance.

3425. *ADVANCED GAGE LABORATORY.* Credit three hours. Prerequisites, 3405, 1221, 1222. One lecture and two laboratory periods a week. An intensive study of gaging practices and standards, as applied to modern industrial manufacture. Application of quality control techniques. Automatic sorting, continuous gaging, a selective-assembly inspection. Ultrasonics, electronics, and pneumatic systems and their use. Radiation inspection. Nondimensional inspection.

3498, 3499. *PROJECT.* Total credit hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

HEAT-POWER ENGINEERING

Messrs. ANDRAE, CLARK, CONTA, DROPKIN, ERDMAN, FAIRCHILD, GAY, KATZ, MACKEY, MONROE, SHEPHERD, and WATSON.

3501. *ENGINEERING THERMODYNAMICS.* Credit four hours. Each term. Two lectures and two recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Fundamental principles of engineering thermodynamics; energy concepts and energy equations; laws of thermodynamics; equi-

librium, availability, and reversibility; thermodynamic properties of fluids, including perfect gases, actual gases, vapors, mixtures; nonflow and flow processes, cycles.

3502. *HEAT-POWER LABORATORY.* Credit two hours. Fall term. One laboratory period a week. Prerequisite, 3501; or 3501 must be taken in the same term. Laboratory study of application, calibration, and accuracy of instruments used in heat-power laboratory, including pressure gages, manometers, planimeters, indicators, tachometers, dynamometers, fluid flow meters, calorimeters, gas analyzers, psychrometers.

3503. *HEAT TRANSFER AND THERMAL MEASUREMENTS.* Credit three hours. Spring term. Two recitations and one laboratory period a week. Prerequisites, 3501, 1155. The fundamentals of heat transfer by conduction, convection, and radiation; heat transfer in engineering apparatus. Laboratory instruction in measurement of temperature, thermal conductivity, and film coefficients of heat transfer.

3504. *FUELS AND COMBUSTION.* Credit two hours. Each term. Two recitations a week. Prerequisite, 3501. A study of the properties of solid, liquid, and gaseous fuels affecting the design and performance of engineering apparatus. Study of the combustion process including combustion in furnaces and engines.

3505. *REFRIGERATION AND AIR CONDITIONING.* Credit three hours. Fall term. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503. Study of the fundamental theory of refrigeration; analysis of compression, absorption, and steam jet systems; refrigerating equipment and engineering applications. Principles and practice in the conditioning of air, including heating, humidifying, cooling, and dehumidifying.

3506. *STEAM POWER.* Credit three hours. Spring term. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. A study of vapor cycles, combustion equipment, draft apparatus, boilers, condensers, evaporators, feedwater heaters, economizers, air preheaters, feed pumps, steam engines, steam turbines and complete plants. Industrial uses of steam, heat, and power.

3507. *COMBUSTION ENGINES.* Credit four hours. Spring term. Three recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. Study of combustion engines with particular emphasis upon thermodynamics and the combustion process. Application and performance of spark-ignition and compression-ignition engines, gas turbines, jet engines, and auxiliaries.

3508. *HEAT-POWER ENGINEERING.* Credit three hours. Fall term. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. Performance and application of spark ignition and compression ignition combustion engines and their auxiliaries; steam power plants and power plant equipment, including steam generators, heat exchangers, pumps, fans.

3509. *HEAT-POWER ENGINEERING.* Credit three hours. Spring term. Two recitations and one laboratory period a week. Prerequisites, 3501, 3502, 3503, 3504. Power plant prime movers, including steam and gas turbines; refrigeration; heating, ventilating, and air conditioning.

3510. *ENGINEERING IN FOOD PROCESSING.* Credit three hours. Fall term. Three lecture-recitation periods a week. Prerequisites, elementary physics and chemistry. Primarily for students in the College of Agriculture and School of Nutrition. Not open to engineering students. An introduction to engineering principles of construction and operation of mechanical and electrical equipment used in the preservation and storage of foods.

3530. *HEAT-POWER ENGINEERING.* Credit three hours. One lecture and two recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Energy concepts and energy equations; thermodynamic properties of gases, vapors, and mixtures; nonflow and flow processes; cycles.

3533. *HEAT-POWER ENGINEERING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 3530. Fuels, combustion, steam-generating units; steam turbines, condensers, combustion engines, and performances of complete power plants.

3541. *HEAT-POWER 1.* Credit three hours. Fall term. Two lectures and one two-hour laboratory or computing period a week. Required of students in the School of Civil Engineering. Prerequisites, Mathematics 161, 162, 163; Physics 116. Energy concepts and energy equations; laws of thermodynamics; properties, processes, and cycles of gases. Internal combustion engines; the compressed air plant.

3542. *HEAT-POWER 2.* Credit two hours. Two lectures a week. Required of students in the School of Civil Engineering. Spring term. Prerequisite, 3541. Properties and processes of vapors; steam engines; steam turbines; the elementary steam power plant. The fundamentals of heat transfer by conduction, convection, and radiation; applications to problems in heat transfer of special interest to students in civil engineering.

3550. *HEAT-POWER RESEARCH.* Credit to depend upon hours of actual work. Recitation and laboratory instruction will be given to a limited number of undergraduates and graduate students interested in work to supplement that given in required courses in the fields of internal combustion engines, power plants, heat transfer, refrigeration, air conditioning, and instruments.

3551. *STEAM TURBINES.* Elective for seniors. Credit two hours. Alternate terms. Two lectures a week. Prerequisite, 3501. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbines in engineering practice.

3553. *TEMPERATURE MEASURING INSTRUMENTS.* Elective for seniors and graduates. Credit two hours. One lecture and one laboratory period a week. Prerequisite, 3503 or equivalent. This course covers the theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, electrical resistance thermometers, thermoelectric thermometers, optical pyrometers, radiation pyrometers, and other temperature measuring devices.

3554. *DIMENSIONAL ANALYSIS.* Elective for juniors and seniors. Credit two hours. Two lecture-recitation periods a week. Dimensions of physical units. Use of dimensional analysis. Derivation of dimensionless constants. Geometric, dynamic, and kinematic similarity. The principles of similitude and their application to solutions of problems with particular stress on the use of dimensional analysis and the principles of similitude in experimental work.

3555. *GRAPHICAL COMPUTATION AND REPRESENTATION.* Elective to undergraduate students who have completed four terms or to graduate students. Credit two hours. Two recitations a week. Design of slide rules, network charts, and alignment charts; derivation of empirical equations to fit experimental data.

3556. *ADVANCED AIR CONDITIONING.* Credit three hours. Two lectures and one laboratory period a week. Prerequisite, 3505 or equivalent. Selected problems in the study of air conditioning principles and apparatus; panel heating and cooling; the heat pump.

3560. *AIRCRAFT POWER PLANTS.* Credit three hours. Three recitations a week. Prerequisite, senior standing. Operating principles and mechanical and

thermal characteristics of reciprocating and rotating types of aircraft power plants. Studies augmented by reading of technical papers and solutions of problems.

3561. *AIRCRAFT ENGINE DESIGN.* Credit three hours. Two laboratory computing periods a week. Prerequisites, 3507, 3353. Engine design principles and pertinent thermodynamic calculations. Design of engine components with regard to functions and loads.

3563. *ADVANCED THERMODYNAMICS.* Credit three hours. Three lectures or recitations per week. Prerequisite, 3501, or equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on the mathematical development and philosophical interpretations. The pure substance, homogeneous and heterogeneous systems; systems influenced by motion, gravity, and electricity. The significance of the Gibbs and Helmholtz functions in engineering thermodynamics; the Maxwell relations. Quantitative treatment of availability and irreversibility; the criteria of equilibrium.

3564. *THERMODYNAMICS OF FLOW OF COMPRESSIBLE FLUIDS.* Intended for graduate students but open to qualified fifth year students. Credit two hours. Two recitations a week. Prerequisites, 3501 and 2331, or equivalents. The basic differential equation for the flow of gases including area change, friction, mass transfer, and heat transfer; the integrated form of this equation for special cases; Fanno and Rayleigh lines, shock phenomena. Applications to flow in ducts, diffusers, and nozzles and to design problems on compressors, turbines, ram jets, rockets, and wind tunnels. Demonstration of compressible flow effects by means of the water channel analogy.

3565. *ADVANCED HEAT TRANSFER.* Intended for graduate students but open to qualified fifth year students. Credit two hours. Two recitations a week. Prerequisites, 3501 and 3503, or equivalents. Applications of the "relaxation" method to the solution of problems on heat transfer in the steady state; extended surfaces and two-dimensional heat flow. Numerical analysis of transient and periodic heat flow. Hydraulic and electric analogues.

3566. *COMBUSTION THEORY.* Intended for graduate students but open to qualified fifth year students. Credit three hours. Three recitations a week. Thermodynamics of combustion, use of statistical mechanics in determining properties of high temperature gases, reaction rates, combustion spectroscopy, radiation, aerodynamics of heat addition in compressible flow, laminar and turbulent conduction of flames, detonation.

3570. *AUTOMATIC CONTROL ENGINEERING.* Credit three hours. Two lectures and one laboratory period a week. Prerequisite or parallel courses, 3502 and 2331. A study of the commercially available automatic controllers commonly used in current industrial practice, with special reference to type of construction, installation requirements, and available control patterns. The problems existing in various plants and processes will be discussed, and the influence of the control modes on process behavior will be studied.

3580. *DIESEL ENGINEERING.* Credit three hours. Two lecture-recitation periods, one laboratory or computing period a week. Prerequisites, 3501, 3507. Consideration will be given, both in the classroom and the laboratory, to design and construction of typical diesel engines, fuel injection systems, combustion chamber design and combustion phenomena, engine governors, supercharging, fuels and lubricants for diesel engines, and engine performance. The objective of this course is to emphasize the basic concepts influencing the performance of a diesel engine and its accessories and to provide an opportunity for experimental study of the characteristics of the diesel engine.

3581. *ADVANCED COMBUSTION ENGINES.* Credit three hours. One recitation and two computing periods a week. Prerequisites, 3501 and 3507. Detailed

study of operation and design of combustion engines for automotive, marine, and industrial uses; special emphasis on the spark-ignition engine; the matching of engine supply power and propulsion demand power.*

3590. *GAS TURBINE PLANTS.* Elective for graduate students and seniors in mechanical engineering. Credit three hours. Three lectures a week. Prerequisite, 3501. Fundamental study of the cycles and apparatus of the modern gas turbine plant; performance and suitability of this type of power plant for various applications.

3591. *PRINCIPLES OF TURBOMACHINERY.* Credit three hours. Three lectures a week. Prerequisites, 3501 and 2331 (or equivalent). The transfer of energy between a fluid and a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors, and turbines.

3598, 3599. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of heat-power engineering. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

ELECTRICAL ENGINEERING

COURSES BY GROUPS . . . Within the School of Electrical Engineering, courses are numbered in groups, with each course designated by a four-digit number in which the first digit is 4. The second digit denotes the course group, and the third and fourth digits identify the course within the group.

The descriptions of courses offered in the School of Electrical Engineering follow. Courses required of students in electrical engineering in other divisions may be found on pages 117-125.

GENERAL COURSES

Messrs. COTTRELL, ERICKSON, and STRONG.

4021. *ENGINEERING REPORTS.* Term 9. Required. Credit three hours. Fall term only. One lecture and one recitation each week. Texts: *Writing the Technical Report,* Nelson; *Report Writing,* Gaum and Graves. The objective of this course is to develop the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present technical reports which meet professional standards.

4041 and 4042. *NONRESIDENT LECTURES.* Terms 9 and 10. Required. Total credit one hour for both terms. Both fall and spring terms. One lecture each week. The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life. With permission of the professor in charge, attendance at other lectures of suitable subject matter may be substituted for attendance at the lectures of this course.

4091 and 4092. *PROJECT.* Terms 9 and 10. Required. Credit three hours for each term. Fall and spring terms, respectively. To develop self-reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his option. The choice of a problem is made by the student after consultation with members of

*Recommended together with Course 3377 for a study of Automotive Engineering.

the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun. Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; design, construction, and testing of special apparatus in which the student is particularly interested. Throughout the work the student is expected to conform to good engineering practice in keeping a complete notebook of day-by-day tests and investigations. At frequent intervals he is required to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN BASIC ELECTRICAL ENGINEERING

Messrs. ANKRUM, BURCKMYER, COTTRELL, JONES, McLEAN, MALTI, OSBORNE, SMITH, and STRONG.

4110, 4111, 4112. *BASIC ELECTRICAL ENGINEERING.* Terms 3, 4, and 5, respectively. Required. Credit three hours each. Two lecture-recitations and one computing period each week.

4110. *BASIC ELECTRICAL ENGINEERING I.* Term 3. Required. Credit three hours. Fall term only. Prerequisites, Mathematics 162, Physics 116, Chemistry 106. This is the first of three successive courses presenting the basic elements of electrical engineering which are common to the several branches of study offered later in the curriculum. They present the basic concepts and laws of electricity with emphasis on analysis and understanding rather than on memorization of formulas, and with concern for their relation to engineering interest. The material in the first course includes the following topics: energy resources, power efficiency, conductors and resistance; electromotive force and sources; measurement of electrical quantities; d-c electrical networks; magnetic quantities and circuits; permanent magnets; magnetic forces; induced e.m.f. and inductance.

4111. *BASIC ELECTRICAL ENGINEERING II.* Term 4. Required. Credit three hours. Spring term only. Prerequisites, Mathematics 163, Physics 117, Chemistry 106. The material in this course includes the following topics: electromagnetic induction; alternating emf; power-distribution circuits; self- and mutual-inductance, coupling reactors; electrostatic energy, fields, and forces; capacitance; transient and alternating currents in circuits with resistance and inductance, in circuits with resistance and capacitance, and in series and parallel circuits with resistance, inductance, and capacitance. Loci.

4112. *ALTERNATING-CURRENT CIRCUITS.* Term 5. Required. Credit three hours. Fall term only. Prerequisite, 4111. Text: *Alternating-Current Circuits,* Kerchner and Corcoran. The study of alternating-current circuits includes the following topics: series-parallel circuits, and loci; a-c networks, and theorems for solution; equivalent circuits; coupled circuits; air-core and iron-core transformers; transmission lines; power-factor correction; three-phase circuits; balanced three-phase relations; three-phase power; measurement of three-phase power and energy; three-phase transmission; determination of phase sequence; nonsine waves in single-phase and in polyphase circuits; harmonics in three-phase circuits.

4113. *TRANSMISSION LINES AND FILTERS.* Term 7 or 8. Credit three hours. Three recitations. Text: *Transmission Lines and Networks,* Johnson. A study of the behavior, over a range of frequencies, of circuits with lumped or distributed elements, including filters of the lattice, constant K and derived types, and of transmission lines in the steady state.

4114. *TRANSIENTS IN LINEAR SYSTEMS.* Term 7 or 8. Credit three hours. Two recitations and one computing period a week. Transient behavior of circuits with lumped constants. The classical solution of single- and double-energy circuits in the transient state. The ordinary linear differential equation. The Laplace transformation of such an equation. The solution of such an equation by Laplace transforms. Systems of ordinary linear differential equations, their Laplace transformation, and their solution.

4116. *ELECTRIC-CIRCUIT LABORATORY.* Term 5. Required. Credit three hours. Fall term only. One lecture and one lecture-laboratory period each week. Prerequisite, 4111. Must be preceded or accompanied by 4112. Text: mimeographed notes, supplemented by reference to *Electrical Measurements,* Laws, and to *Electrical Engineering,* Strong. This course and the two machinery laboratory courses which follow it, 4216 and 4226, require for each topic a preparatory study of references, a laboratory experiment, a written report consisting primarily of solutions of problems based on laboratory and other data, and a group discussion of the reports. The principal topics studied are basic direct-current circuits, with constant and with varying resistors; application and analysis of circuits in bridges and in other measuring apparatus; thermocouple circuits; temperature measurement and the basic steady-state heat-flow conditions in electrical machines; construction, characteristics, and circuit connections of permanent-magnet moving-coil instruments and of the wattmeter; equipment, procedure, and circuits used in calibrating, checking, and standardizing electrical instruments and secondary standards; the construction, characteristics, and circuit connection of copper-oxide rectifiers and of instruments for measuring alternating voltage and alternating current; characteristics of ideal and of practical resistors, inductors, and capacitors; characteristics of single-phase circuits under approximately sinusoidal conditions of wave form, at power frequencies; characteristics of thermal circuits under elementary transient conditions.

4121. *ELECTRON TUBES AND CIRCUITS.* Term 6. Credit four hours. Spring term only. Two lecture-recitations, one computing period, and one laboratory each week. Prerequisite, 4112. Text: *Basic Electronics,* Ankrum. This is the first of a group of courses which present and expand the fundamental laws of electron behavior and correlate such behavior with the functioning of simple electronic circuits. The material includes the theory of matter and of electron emission; emitters, conduction in high-vacuum and in gas; photoelectric cells; the construction, characteristics, and control of the cathode-ray tube; characteristics of high-vacuum crystal and of thermionic gas diodes; cold electrode gas discharge tubes; rectification and filtering with L-section and π-section filters; studies of the operation and application of thyratrons, pool-type tubes, polyphase rectifiers, and electronic light sources.

4122. *ELECTRONIC CIRCUIT ELEMENTS.* Term 7. Required. Credit four hours. Fall term only. Two lecture-recitations, one computing period, and one laboratory each week. Prerequisite, 4121. Text: *Basic Electronics,* Ankrum. Topics include high-vacuum triode characteristics, tube parometers, and equivalent circuits; transistor characteristics, parometers, and equivalent circuits; multi-grid vacuum-tube characteristics; application of linear equivalent circuits in devices using multi-element high-vacuum tubes; studies of air-core and iron-core transformers as used in communication systems; studies of Class A, Class B, and Class C amplifiers; studies of feedback systems including both positive and negative feedback.

4123. *ELECTRONIC CIRCUIT ELEMENTS.* Term 8. Required. Credit four hours. Spring term only. Two lecture-recitations, one computing period, and one laboratory each week. Prerequisite, 4122. Topics include studies of non-linear circuits used for amplitude modulation and for angular modulations; studies of non-linear circuits used for demodulation of amplitude modulation and of angular

modulation; studies of multi-vibration and blocking oscillators; simple wave-shaping circuits, and wave-shaping circuits involving feedback; elements of electronic computers.

COURSES IN MACHINERY

Messrs. BURCKMYER, OSBORNE, TUTTLE, and VRANA.

4216. *ELECTRICAL MACHINERY LABORATORY.* Term 6. Required. Credit four hours. Spring term only. One lecture, one recitation, and one lecture-laboratory period each week. Prerequisites, 4116 and 4211. Text: mimeographed notes. Following a study of direct-current magnetization in general and the magnetic circuits of dynamos, the course proceeds to measured and predicted characteristics of direct-current generators and motors with all common methods of excitation; characteristics of generators in parallel; detection and correction of faulty commutation; construction, connection, and operating characteristics of typical direct-current motor controllers; measurement of segregated losses, and prediction of efficiency of dynamos by mechanical-drive and by retardation methods; characteristics and typical applications of the Amplidyne. There is also a continuation of the study of elementary single-phase a-c circuits, and a study of a-c bridge circuits and the detectors commonly used in such circuits.

4221. *ALTERNATING-CURRENT MACHINERY.* Term 7. Required. Credit three hours. Fall term only. Two recitations and one computing period each week. Prerequisite, 4112. Text: *Alternating Current Machinery,* Bryant and Johnson. A study is made of the construction, operating characteristics, applications, and control of transformers, synchronous machines, and single-phase and polyphase induction motors. Among the topics are equivalent-circuit diagrams; regulation; losses and efficiency; single-phase and polyphase connection of transformers; parallel operation of synchronous generators; circle diagrams of polyphase induction motors. Vector diagrams and graphical methods are used extensively.

4226. *ELECTRICAL MACHINERY LABORATORY.* Term 8. Required. Credit four hours. Spring term only. One lecture, one recitation, and one lecture-laboratory period each week. Prerequisites, 4216 and 4221. Text: mimeographed notes. The course begins with a general study of basic principles of alternating-current magnetization and circuit relations involving nonsinusoidal current and voltage, including detailed analysis of balanced and unbalanced polyphase circuits in which harmonics arise in the load or in the generator. Application of these principles is then made in analyzing selected operating characteristics of single-phase constant-potential transformers, single-phase and three-phase induction motors, and synchronous motors and generators, including parallel operation of the latter.

COURSES IN POWER

Messrs. BRYANT, LINKE, McILROY, ERICKSON, and ZIMMERMAN.

4321. *ELECTRICAL MACHINE THEORY.* Elective. Credit three hours. Fall term only. Three recitations each week. Prerequisite, 4221. Text: *Alternating-Current Machinery,* Tarboux. This course extends the analysis of certain subjects of the prerequisite course. Among its topics are analysis of magnetomotive force and of air-gap flux in synchronous and in induction machines for harmonics in time and in space; effects of such harmonics on induced voltage and on torque; two-reaction analysis of salient-pole synchronous machines; analyses of single-phase induction motors and commutator alternating-current motors.

4326. *POWER LABORATORY.* Elective. Credit three hours. Spring term only. One lecture and one lecture-laboratory period each week. Prerequisites, 4226 and 4321. Text: mimeographed notes. This course continues the study of basic principles of alternating-current magnetization and the exemplification of these prin-

ciples under the favorable conditions provided by selected transformers. Salient-pole synchronous-machine principles are examined from the standpoint of the two-reaction theory. The reactances are measured by several methods, and the theory is applied to the analysis of torque-angle relations, steady-state stability, and the voltage regulation of generators. The measurement and the significance of the transient reactances are briefly studied. The special combinations of conditions that arise in commutating alternating-current motors are analyzed for a selected machine. The course includes circuit studies applied to selected alternating-current bridges and to symmetrical-component analysis of faults on transmission lines.

4331. *ELECTRICAL DESIGN ECONOMICS.* Term 9. Elective. Credit three hours. Fall term only. Two recitations and one computing period each week. Prerequisites, 4211 and 4221. Text: *Elements of Electrical Design,* Still; mimeographed notes. The object of the course is to acquaint the student with technical and economic problems encountered in the design of resistors, electromagnets, cables, condensers and condenser bushings, transformers, and rotating electrical machines.

4334. *ECONOMICS OF PUBLIC UTILITIES.* Elective. Credit two hours. Two recitations each week. Prerequisite, Economics 107. Text: *Principles of Engineering Economy,* Grant. The principles underlying the selection of the most economical method of accomplishing an engineering objective are developed. These include cost of interest, depreciation, return on investment, planning of plant expansion, and the theory and practice of setting rates for utility service. Most of the illustrative examples and problems are taken from the electric public utility field.

4341. *MOTOR CONTROL.* Elective. Credit two hours. Fall term only. One lecture and one recitation each week. Prerequisite, 4226. Text: *Electric Motors in Industry,* Rife, Shoults, and Johnson. The course is a study of the design and the functioning of typical controllers and protective devices for direct-current and alternating-current motors. Among the topics are problems of manual and automatic acceleration, dynamic braking, power regeneration, plugging, and voltage control for direct-current motors; design of resistors and magnetic contactors; interpretation of controller diagrams.

4342. *APPLICATION OF MOTORS.* Elective. Credit three hours. One lecture, one recitation, and one computing period each week. Prerequisite, 4341. Text: *Electric Motors in Industry,* Rife, Shoults, and Johnson. Characteristics of motors and requirements of typical loads are analyzed and correlated so that a proper motor may be selected. The course includes a study of motor duty cycles, adjustable-speed alternating-current drives, coordinated-drive systems, and "synchro" systems. Inspection trips may replace several of the computing periods.

4361. *POWER SYSTEMS.* Elective. Credit three hours. Fall term only. Two lectures and one computing period each week. Prerequisite, 4221. Text: *Electric Power Equipment,* Tarboux. The function and form of the electrical apparatus included in modern power systems are studied. Among the power system components considered are generators, switchgear, protective devices, power transformers, converters, transmission line towers and conductors, and voltage regulating devices. Inspection trips to near-by power stations are planned to supplement classroom discussions.

4362. *TRANSMISSION OF ELECTRIC ENERGY.* Elective. Credit three hours. Spring term only. Two lectures and one computing period each week. Prerequisites, 4311 and 4361. Text: *Introduction to Electric Power Systems,* Tarboux. The performance of transmission lines is analyzed through the following sequence of topics: evaluation of transmission line parameters from the physical dimensions of the circuit; expressions for voltage and for current at sending and

at receiving ends; classification of lines as short, moderately long, and long; equivalent π and T networks; development of circle diagrams to facilitate calculations of performance.

4363. *STABILITY OF ELECTRIC POWER SYSTEMS.* Elective. Credit two hours. Two lectures each week. Must be preceded or accompanied by 4362. Text: *Power System Stability,* Vol. I, Kimbark. The conditions of stability of synchronous machines and of electric-power systems under both steady and transient conditions are investigated.

4364. *PROTECTION AND RELAYING ON POWER CIRCUITS.* Elective. Credit three hours. Three lectures each week. Must be preceded or accompanied by 4371. Text: mimeographed notes supplemented by manufacturers' bulletins. The principles of the operation of typical relays and of the application of relaying systems are considered. The course includes a study of telemetering and supervisory-control equipment.

4365. *SYMMETRICAL COMPONENTS.* Elective. Credit three hours. Three lectures each week. Prerequisites, 4311, 4321, and 4361. Text: *Circuit Analysis of A-C Power Systems,* Clarke. The fundamental concept of symmetrical components is developed, and is applied to the study of steady-state unbalanced loading of rotating machines, transformers, and power transmission lines. Methods of analyzing the transient behavior of power systems under unbalanced faults are developed and are illustrated by problems. A study is made of the impedances of transmission lines to the several symmetrical components of current.

4371. *HIGH-VOLTAGE PHENOMENA.* Elective. Credit three hours. Two lectures and one lecture-computing period each week. Prerequisite, 4362. Text: mimeographed notes. The course is a study of the problems encountered in the normal operation of electric-power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions.

COURSES IN INDUSTRIAL ELECTRONICS

Messrs. COTNER and NORTHROP.

4411. *ELECTRONIC CONTROL EQUIPMENT.* Elective. Credit three hours. Fall term only. Two lectures and one lecture-laboratory period each week. Prerequisite, 4122. Text: mimeographed notes. The course deals with the principles of electronic instrumentation and electronic control systems. A study is made of the methods of interpreting electronically a stimulus appearing in the form of heat, light, sound, or mechanical movement; and of typical electronic circuits through which such electrical effect causes the controlled device to make the desired response. Among these circuits are timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators, and frequency-varying and frequency-discriminating circuits.

4415. *ADVANCED ELECTRONIC CONTROLS.* Elective. Credit three hours. Two recitations and one computing period each week. Prerequisite, 4411. Text: references and mimeographed notes. This course is an intensive study of the theory and the operating characteristics of electronic circuits and equipment used to control and regulate welders, motors, generators, and other machines. These circuits are generalized, compared, and analyzed rigorously. Methods of precise control of time intervals, voltage, current, and frequency are included.

4421. *ELECTRONIC POWER CONVERTERS.* Elective. Credit three hours. Spring term only. Two lectures and one lecture-laboratory period each week. Pre-

requisite, 4411. Text: mimeographed notes. This course continues the study of the characteristics and the application of some of the electronic power converting devices that were considered in introductory courses, such as power amplifiers, oscillators, single-phase and polyphase rectifiers and inverters, X-ray equipment, and welders. Laboratory work includes inspection and testing of typical equipment, with an analysis of performance.

COURSES IN RADIO AND COMMUNICATION

Messrs. BOOKER, CREDLE, INGALLS, JONES, McGAUGHAN, McLEAN, and SMITH.

4511. *RADIO AND COMMUNICATION THEORY.* Elective. Credit three hours. Fall term only. Two lectures and one computing period each week. Prerequisite, 4122. Texts: *Vacuum Tube Circuits,* Arguimbau; supplementary notes. The course includes a study of video amplifiers, feedback amplifiers, oscillators, mixer circuits, pulse-shaping circuits, and noise; and the integration of circuit components into complete transmitters and receivers. Both amplitude-modulated and frequency-modulated equipment are considered.

4512. *RADIO AND COMMUNICATION THEORY.* Elective. Credit three hours. Spring term only. Two lectures and one recitation or computing period each week. Prerequisite, 4122. Text: *Theory and Applications of Microwaves,* Bronwell and Beam; supplementary notes. This course is a study of communication circuits with distributed constants and also a study of production and propagation of electromagnetic radiation. Topics include transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation.

4516. *RADIO AND COMMUNICATION LABORATORY.* Term 9. Required in Radio and Communication group. Credit three hours. Fall term only. One recitation and one laboratory period each week. Must be preceded or accompanied by 4511. Text: *Radio Engineer's Handbook,* Terman; *Radiotron Designer's Handbook,* 3d ed., F. L. Smith; supplementary notes. This course consists of a series of experiments based upon the work of 4511.

4517. *RADIO AND COMMUNICATION LABORATORY.* Elective. Credit three hours. Spring term only. One recitation and one laboratory period each week. Must be preceded or accompanied by 4512. Texts: *Radio Engineer's Handbook,* Terman; *Radiotron Designer's Handbook,* 3d ed., F. L. Smith; supplementary notes. This course consists of a series of experiments based upon the work of 4512.

4518. *COMMUNICATION EQUIPMENT SHOP.* Term 9. Required in Radio and Communication group. Credit one hour. Fall term only. One lecture-laboratory period each week. Prerequisite, 4122. Text: mimeographed notes. During the term some equipment such as a small radio receiver, amplifier, or other electronic device is constructed and tested. Experience is gained in the use of hand tools and in circuit layout in accordance with good construction practice. Circuit components are studied in terms of their application in electronic circuits.

4521. *RADIO BROADCASTING.* Elective. Credit three hours. Two lectures and one lecture-laboratory or computing period each week. Prerequisite, 4511. Text: references to current manuals and literature. The course deals with the engineering aspects of radio broadcasting, including studio equipment, and problems of studio operation; transmitting equipment, and problems of operation; determination of coverage; station interference, allocation of channels, and use of directional radiating systems; performance tests and maintenance procedures; net-

work interconnections; purpose and policy of governmental regulating bodies. The alternate laboratory and computing periods offer an opportunity to gain practical knowledge through the facilities of the University broadcasting station and through inspection of other near-by stations.

4522. *TELEPHONE AND TELEGRAPH SYSTEMS.* Elective. Credit two hours. Two recitations each week. Text: *Electrical Communication,* Albert. This course continues in greater detail the study begun in the prerequisite course. The methods of machine switching in telephone systems are studied. Consideration is given to the relative advantages of the several systems, and to the proper choice of system as influenced by the size of the community. Carrier telephony in both cable and open-wire circuits is given some attention. Modern telegraphic methods, such as multiplex printing and facsimile transmission, are studied. Inspection trips to near-by telephone and telegraph exchanges will be arranged.

4526. *DESIGN AND CONSTRUCTION OF VACUUM TUBES I.* Elective. Credit three hours. Two lecture-recitations, and one laboratory period each week. Prerequisite, 4122. Text: *Vacuum Tubes,* Spangenberg. The purpose is to acquaint the student with methods by which an electron tube may be designed and its performance predicted and to give a practical insight into the methods and problems of electron tube manufacture. Materials and processing necessary to fabricate simple tubes are discussed. Design considerations involved in heater and cathode design are covered. The theoretical aspects of diode design are taken up, followed by triode, tetrode, beam tubes, converter tubes and other special vacuum tube types. Current manufacturing practices are discussed and illustrated. The laboratory courses are devoted to the actual construction of several forms of the types considered from the theoretical point of view. The student assembles the elements, completes the necessary glass working and evacuation, and compares the performance with that predicted.

4527. *DESIGN AND CONSTRUCTION OF VACUUM TUBES II.* Elective. Credit three hours. Two lecture-recitations and one laboratory period each week. Prerequisite, 4526. Text: *Vacuum Tubes,* Spangenberg. This course continues the work begun in 4526. The subjects covered include electron beam formation, cathode ray gun design, traveling wave tube construction, ultra-high-frequency tubes utilizing disc seals and other methods of construction. Gas-filled tubes and photo-emissive devices are also considered. The use of the electrolytic tank for gun design is demonstrated. Simple structures illustrating the various constructions and methods are built in the laboratory by the students. During the course the student is permitted to carry out the design and fabrication of a tube structure of his own choosing.

4531. *TELEVISION SYSTEMS.* Elective. Credit three hours. Two lectures and one laboratory or computing period each week. Prerequisite, 4511. Texts: *Principles of Television Engineering,* Fink; Television, Vols. III and IV, RCA *Review; Transients in Linear Systems,* Gardner and Barnes. The objectives of the course are to demonstrate the application of physical principles in the field of television engineering and to acquaint the student with modern practice in the design and operation of television transmitters and receivers. Basic work in transient analysis, vacuum tube amplifiers, cathode-ray pickup and viewing tubes, cathode-ray beam deflection, pulse shaping, modulation, and antenna characteristics serves as a background for further study of television problems. In addition, such problems as optics, illumination, scanning, synchronization, blanking, and shading are considered. Computations involving the design of various units required for transmission and reception are carried out in the computing periods. Laboratory work consists of experimental work on problems jointly selected by the student and instructor in the field of television and related fields. An inspection of near-by television facilities serves to emphasize practical aspects.

4541. *APPLIED ACOUSTICS.* Elective. Credit two hours. Two recitations each week. Prerequisites, 4122 and 4131. Texts: *Applied Acoustics,* Olsen and Massa; *Vibration and Sound,* Morse. A review of the laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves precedes a study of the transmission of sound through tubes, horns, and unbounded media. The design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders in keeping with acoustical principles is considered. The phenomena of reflection, absorption, and reverberation and the limitations which these phenomena impose upon architectural design are studied. A brief study of record processing and duplication is included.

4551. *RADIO AIDS TO NAVIGATION.* Elective. Credit two hours. Two recitations each week. Prerequisites, 4122 and 4131. Text: *Radar Aids to Navigation,* Hall; selected references. Analysis of the principles of directive antennas is followed by discussion of long-wave and medium-wave direction finders and radio beacons. Atmospheric effects and limitations on the accuracy of determinations made by such equipment are considered. Attention is also given to medium-frequency pulsed transit-time systems and to high-frequency return-signal systems, with application to long-range navigation and precision mapping. Airport approach systems and traffic control are studied briefly.

4561. *ULTRA-HIGH-FREQUENCY SYSTEMS.* Elective. Credit two hours. One recitation and one laboratory period each week. Prerequisites, 4512 and 4517. This course consists of a theoretical and laboratory study of electrical equipment particularly applicable to ultra-high-frequency operation, such as magnetrons, klystrons, and other similar generators; measuring devices, transmission systems, wave guides, coaxial lines, radiators, and cavity resonators.

4563. *PULSE TECHNIQUE IN COMMUNICATION AND RADAR.* Elective. Credit three hours. Three recitations each week. Prerequisites, 4511 and 4516. Texts: *Principles of Radar,* M.I.T. Radar School Staff; supplementary notes. This course deals with the transmission of information and the detection of objects by means of discrete pulses rather than by continuous waves. Among its topics are analysis of signal functions, especially of pulses and related signals; noise analysis; basic principles of pulse generation, modulation, transmission, and reception; fundamental circuits of pulse techniques; application to radar; pulse communication systems, known as pulse-amplitude, pulse-time, pulse-position and pulse-code modulating systems.

4564. *TRANSMISSION OF INFORMATION.* Elective. Credit three hours. Three recitations each week. Prerequisite, 4563. Text: mimeographed notes. This course deals with the general aspects of a transmission system, which consist of the source of information, the transmitter, the channel, the receiver, and the final destination of the message. The definition of information and a quantitative measure of information are given. The statistical properties of the source, its entropy, and the rate at which information is produced by the source are discussed. The transformation of primary signal functions into secondary signal functions at the transmitter, the capacity of the channel to transmit the secondary signal function in the presence of channel noise, and the possibilities of recovering the primary signal function at the receiver are studied. The over-all performance of transmission is discussed as to fidelity considerations and the effective rate of transmission. These principles are applied to pulse-code modulation as an example of modern transmission of information.

4565. *ELECTROMAGNETIC THEORY.* Elective. Credit three hours. Prerequisite, 4512. Three lecture-recitations each week. Texts: *Electric and Magnetic Fields,* Attwood; *Networks, Lines and Fields,* Rider; *Electromagnetic Theory,* Stratton; *Electromagnetic Waves,* Schelkunoff. The foundations of electromagnetic theory required for study of radio wave communication. The course proceeds from

a critical examination of the significance of the electromagnetic vectors and their relations to a discussion of the principles involved in guided and unguided propagation.

4566. *RADIO WAVES I.* Elective. Credit three hours. Prerequisite, 4565. Three lecture-recitations each week. Texts: *The Upper Atmosphere,* Mitra; *Radio Wave Propagation,* Burrows and Attwood; *Meteorological Factors in Radio Wave Propagation,* Appleton; *Terrestrial Radio Waves,* Bremmer. This course, together with 4567, describes how propagation of radio waves is influenced by the earth, the lower atmosphere, and the ionosphere. Topics introduced are the Sommerfeld theory of propagation over a flat earth, diffraction round a spherical earth, superrefractive propagation in atmospheric ducts, propagation in an ionized atmosphere, reflection from the ionosphere at both normal and oblique incidence.

4567. *RADIO WAVES II.* Elective. Credit three hours. Prerequisite, 4566. Three lecture-recitations each week. A continuation of 4566. The influence of the earth's magnetic field upon ionospheric propagation, the extraterrestrial phenomena that affect propagation of radio waves in the earth's atmosphere.

4568. *ANTENNAS.* Elective. Credit three hours. Prerequisite, 4565. Three lecture-recitations each week. The theory of transmission and reception by dipoles, slots, broadside antennas, end-fire antennas, horns, and paraboloids; the detailed electromagnetic field involved in simple antennas.

4571. *ADVANCED COMMUNICATION NETWORKS.* Elective. Credit three hours. Three recitations each week. Prerequisite, 4513. Text: *Network Analysis,* Bode. The analysis and synthesis of networks. Among the topics are mesh and nodal analysis, the complex frequency plane, conditions for physical realizability, representation of driving-point impedance functions by physical networks, topics in the design of impedance functions.

COURSES IN ILLUMINATION

Messrs. COTTRELL and STRONG.

4611. *INTRODUCTORY ILLUMINATION.* Elective. Credit three hours. Fall term only. Two recitations and one laboratory-computing period each week. Prerequisite, Physics 118. Text: *Scientific Basis of Illuminating Engineering,* Moon. The course is intended to acquaint the student with the general nature of the field of illuminating engineering. Introductory study in several basic aspects of the subject is sufficiently pursued to provide an appreciation of the problems commonly encountered and the methods of solution. Topics are sources of light; visual perception and illusion; light control, both spectral and directional; the units and the measurement of the strength of light sources and of the intensity of illumination; general illumination design; perception, production, and mixing of colors; shadows, desirable and undesirable; architectural objectives.

4612. *ILLUMINATING ENGINEERING.* Elective. Credit three hours. Spring term only. Two recitations and one laboratory-computing period each week. Prerequisite, 4611. Text: *Scientific Basis of Illuminating Engineering,* Moon. This course extends the study of some of the topics introduced in the prerequisite course. Study of current literature supplements the text. Computation of light-flux distribution and study of more difficult lighting problems are pursued. Emphasis is placed on industrial lighting problems more specialized than the problems of general lighting.

4615. *ILLUMINATION SEMINAR.* Elective. Credit two hours. Fall term only, on sufficient demand. One two-hour period each week. Must be accompanied by 4611. Reports on selected topics of current interest in illuminating engineering are presented and discussed.

COURSES IN SERVOMECHANISMS

Messrs. MESERVE and ROSSON.

4711. *SERVOMECHANISM I.* Elective. Credit three hours. Fall term only. Two lecture-recitations and one laboratory or computing period each week. Prerequisites, 4121, 4126, 4216, and 4221. Text: *Servomechanisms,* Chestnut and Mayer. The course is a study of the principles of servomechanisms and regulating systems, principally from the classical differential-equation approach, with applications in industrial control problems. The topics include open-ended and closed-loop controls; differential devices; and follow-up links. Attention is given to factors affecting error, damping, and speed of response, and to the criteria for stability.

4712. *SERVOMECHANISM II.* Elective. Credit three hours. Spring term only. Two lecture-recitations and one laboratory or computing period each week. Prerequisite, 4711. Text: *Principles of Servomechanisms,* Brown and Campbell. Servomechanism theory is here approached from the point of view of Laplace transform analysis. Control systems are synthesized, and their performance is predicted by the use of stability criteria. The course includes laboratory tests for the comparison of observed and predicted performance of servo systems.

ELECTRICAL COURSES REQUIRED IN OTHER ENGINEERING CURRICULA

Messrs. BRYANT, COTTRELL, ERICKSON, LINKE, MESERVE, and STRONG.

4931. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering, civil engineering, and mechanical engineering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one computing period each week. Prerequisites, Mathematics 163, Physics 117, and Mechanics 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; and instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering, civil engineering, and mechanical engineering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4931. The course is intended to develop a general understanding of d-c generators and motors, motor starters and controllers, transformers, induction motors, synchronous machines, a-c single-phase motors, and d-c and a-c selsyn units. All machines are considered as to construction, theory of operation, and operating characteristics.

4933. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering and mechanical engineering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4932. The aim is to develop an understanding of the possibilities of electronic control. Included is a study of the characteristics and applications of the various commonly used electron tubes and a study of such general topics as rectifiers, amplifiers, and oscillators. Quantitative analysis is avoided except when it might aid in understanding the function of a circuit.

4934. *PRINCIPLES OF AUTOMATIC CONTROL.* Term 10. Required of mechanical engineering students in Option A. Credit three hours. Spring term only. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4933. A study of the mathematics of automatic control as exemplified in servo devices, with analysis of electrical, mechanical, and hydraulic

applications. Considerable attention is given to problems of electrical instrumentation in automatically controlled operations and processes.

4981. *BASIC ELECTRICAL ENGINEERING.* Term 4. Required of students in engineering physics. Credit three hours. Spring term only. Two recitations and one computing period each week. Prerequisites, Mathematics 163, Physics 117, Chemistry 106. Text: *Electrical Engineering,* Strong. This is the first of two successive courses presenting the basic elements of electrical engineering common to the several branches of study which follow. They present the elemental concepts and laws of electricity and their application with emphasis on analysis rather than the memorization of formulas. The student is encouraged to regard the physical significance of problems and to question the mathematical result of a combination of formulated principles. The material covered in the first course is identified with the following topics: conductors and resistance; electrical measuring instruments; resistance measurement; electromotive force and its sources; electromagnetic induction; alternating emf; power-distribution circuits; d-c electrical networks and methods of solution; conductors of nonuniform section or material; mapping of current paths; magnetics, magnetic circuits and forces; electromagnets; self- and mutual inductance, coupling, reactors; electrostatic energy, fields, and forces; capacitance; transient and alternating currents in circuits with resistance and inductance, in circuits with resistance and capacitance, and in series circuits with resistance, inductance, and capacitance.

4982. *ALTERNATING-CURRENT CIRCUITS.* Term 5. Required of students in engineering physics. Credit three hours. Fall term only. Two recitations and one computing period each week. Prerequisites, 4111 and Mathematics 607. Text: *Alternating-Current Circuits,* Kerchner and Corcoran. The study of alternating-current circuits is made under the following topics: average and effective values; vectors and vector algebra; power and power factor; series circuits; series resonance, and loci; parallel circuits; series-parallel circuits, and loci; a-c networks, and theorems for solution; equivalent circuits; coupled circuits; air-core and iron-core transformers; transmission lines; power-factor correction; three-phase circuits; balanced three-phase relations; three-phase power; measurement of three-phase power and energy; three-phase transmission; determination of phase sequence; non-sine waves in single-phase and in polyphase circuits; harmonics in three-phase circuits.

4991. *ELECTRONIC CIRCUITS.* Elective. Credit three hours. Three lecture-recitations each week. Prerequisites, 4933 and Mathematics 200, or equivalent. Texts: Selected references and mimeographed notes. This course is offered to graduate students who are majoring in an engineering field other than electrical. It is designed to supplement the basic electronic work normally included in an undergraduate program. Circuits including diodes, triodes, pentodes, and other high-vacuum multi-element tubes are considered. Among the topics discussed are amplifiers, degenerative and regenerative feedback, modulation and demodulation, and pulse shaping.

CHEMICAL AND METALLURGICAL ENGINEERING

Required courses in the chemical and metallurgical engineering curricula given outside the school:

Chemistry 111, 112. Introductory Inorganic Chemistry (p. 119)
115, 116. Introductory Chemistry Laboratory (p. 119)
220. Introductory Quantitative Analysis (p. 119)
222. Introductory Quantitative Laboratory (p. 119)

307, 308. Introductory Organic Chemistry (p. 120)
311. Introductory Organic Laboratory (p. 120)
312. Intermediate Organic Laboratory (p. 120)
403, 404. Introductory Physical Chemistry (p. 120)
411, 412. Introductory Physical Laboratory (p. 120)
English 111, 112. Introductory Course (p. 121)
Electrical Engineering 4931, 4932, 4933 (p. 109)
Geology 712, Metallurgical Raw Materials (p. 121)
History 165, 166. Science in Western Civilization (p. 121)
Mathematics 161, 162, 163. Analytical Geometry and Calculus (p. 122)
Mechanics and Materials of Engineering (p. 69)
Mechanical Engineering Courses (p. 88)
Physics 115. Mechanics (p. 122)
116. Wave Motion, Sound, and Heat (p. 123)
117. Electricity and Magnetism (p. 123)
118. Physical Electronics and Optics (p. 123)
Public Speaking 101 (p. 124)

CHEMICAL ENGINEERING

5103. *CHEMICAL ENGINEERING THERMODYNAMICS.* Fall term. Credit three hours. Prerequisites, Chemistry 403 and 404. Mr. VON BERG.

Lectures. The development of the fundamental principles of thermodynamics, with special attention to their application to chemical engineering processes.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Spring term. Credit three hours a term. Prerequisite, 5103. Mr. VON BERG.

Lectures. Continuation of 5103.

5106. *CHEMICAL ENGINEERING KINETICS.* Credit two hours. Spring term. Two lectures a week. Prerequisite, 5104. Mr. VON BERG.

The kinetics of chemical engineering reactions and processes.

5203, 5204. *CHEMICAL ENGINEERING TECHNOLOGY.* Credit two hours a term. Consecutive terms. Lectures. Mr. WIEGANDT.

A discussion of the important chemical engineering processes and industries. The first term is devoted to the consideration of inorganic chemical technology; in the second term, the discussion deals with the organic chemical engineering industries.

5303, 5404. *UNIT OPERATIONS OF CHEMICAL ENGINEERING.* Credit three hours a term. Consecutive terms. Lectures. Chemistry 403 and Engineering 5203 and 5204. Mr. RHODES. Parallel course.

A critical discussion of the unit operations of chemical engineering.

5353, 5354. *UNIT OPERATIONS LABORATORY.* Credit three hours a term. Two terms. Parallel courses, 5303, 5404. Messrs. RHODES, SMITH, and assistants.

5501. *CHEMICAL ENGINEERING STOICHIOMETRY.* Two hours credit. Lectures and recitations. Mr. RHODES.

Material balances and energy balances in chemical engineering; combustion reactions.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Credit two hours a term. Consecutive terms. Conferences and lectures. Prerequisite or parallel course, 5304. Mr. WINDING.

Problems in fluid flow and heat transfer, distillation, evaporation, drying, humidification and air conditioning, and filtration.

5505. *ADVANCED PROBLEMS IN HEAT TRANSFER.* Credit two hours. Spring term. Conferences and lectures. Prerequisite, 5503 or equivalent. Mr. SMITH.

Advanced topics in heat transfer. Heat transfer to fluids in streamline flow; heat transfer under unsteady-state conditions; heat transmission in mixed-flow heat exchangers, etc. Primarily for graduate students.

5506. *ADVANCED PROBLEMS IN DIFFUSIONAL OPERATIONS.* Credit three hours. Fall term. Primarily for graduate students. Prerequisites, 5503, 5504, or equivalent. Mr. WINDING.

Conferences and lectures. Advanced topics in distillation, gas absorption, liquid-liquid extraction, and drying.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT.* Credit two hours a term. Two lectures a week. Prerequisite, 5304. Mr. SMITH.

Details of design and construction of chemical engineering equipment; piping, design of pressure vessels, detailed design of process equipment.

5605, 5606. *CHEMICAL PLANT DESIGN.* Credit two hours a term. Two terms. Messrs. RHODES, WINDING, HEDRICK, SMITH, VON BERG, and WIEGANDT.

Individual problems in the design of complete chemical plants, with estimation of costs of construction and operation.

5701. *PLANT INSPECTIONS.* Credit one hour. Spring term. Messrs. RHODES and WINDING.

A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries. Each student is required to submit a critical and comprehensive report.

5711. *LIBRARY USE AND PATENTS.* Credit one hour. Fall term. Messrs. RHODES and MASON.

The effective use of technical literature; literature searches; abstracts and bibliographies; patent law.

5741. *PETROLEUM REFINING.* Credit three hours. Alternate terms. Three lectures a week. Prerequisite, 5304. Mr. WIEGANDT. Processes employed in petroleum refining.

5742. *SYNTHETIC RESINS AND PLASTICS.* Credit three hours. Alternate terms. Prerequisite, Chemistry 404. Mr. WINDING.

Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers.

5745. *CONTROL OF ENGINEERING PROCESSES.* Credit three hours. Fall term. Lectures. Hours to be arranged. Prerequisites, 5304 and 5354 or 6204 and 6254. Mr. RHODES.

The methods used for operation control and quality control in chemical engineering processes.

5746. *CHEMICAL ENGINEERING ECONOMICS.* Credit three hours. Spring term. Three lectures each week. Prerequisite, 5304 or special permission. Mr. HEDRICK.

The economic aspects of research, development, manufacturing, and sales in the chemical industries.

5851. *CHEMICAL MICROSCOPY.* Credit three hours. Either term. One lecture and two laboratory periods each week. Prerequisite or parallel courses, Chemistry 403, 404 or 407, 408 and Physics 117, 118 or special permission. Mr. MASON and assistants.

The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical characteristics and

physical chemistry of crystals; lens systems and photomicrography; study of industrial materials such as textile and paper fibers.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).* Credit two or more hours. Either term. Laboratory periods to be arranged. Prerequisite, 5851. Mr. MASON.

Laboratory practice in the analysis of inorganic substances containing the more common elements.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Credit one or more hours. Either term. Prerequisite, 5851 and special permission. Mr. MASON and assistants.

Laboratory practice in special methods and special applications of chemical microscopy.

5953, 5954. *SENIOR PROJECT.* Credit three hours a term; additional credit by special permission. Consecutive terms. Prerequisite, 5304. Messrs. RHODES, MASON, WINDING, SMITH, VON BERG, and WIEGANDT.

Research on an original problem in chemical engineering.

5955. *SPECIAL PROJECTS IN CHEMICAL ENGINEERING.* Credit variable. Either term. Prerequisite, 5954. Messrs. RHODES, MASON, WINDING, SMITH, VON BERG, and WIEGANDT.

Research or studies of special problems in chemical engineering.

METALLURGICAL ENGINEERING

6110. *CASTING, WORKING, AND WELDING OF METALS.* Credit two hours. Either term. One lecture and one laboratory period each week. Messrs. KYLE, HARPER, HODGES, and JOYCE.

An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals.

6111. *INTRODUCTORY METALLURGY.* For students in metallurgical engineering. Credit two hours. Fall term. One lecture and one laboratory period each week. Messrs. KYLE, HARPER, HODGES, and JOYCE.

An elementary course covering the important principles of metallurgy.

6113. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit three hours. Fall term. Two lectures and one laboratory period each week. Prerequisites, 1231 and 6110. Messrs. KYLE, BURTON, and assistants.

An advanced course for students in mechanical engineering covering the application of metallurgical principles to foundry, metal working, and welding problems.

6114. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit three hours. Spring term. Two lectures and one laboratory period each week. Prerequisites, 6111 and 6811. Messrs. BURTON and HARPER. For students in metallurgical engineering. A critical study of selected processes in the fields of casting, metal forming and working, welding, and powder metallurgy. Emphasis is placed on the metallurgical principles involved, the metallurgical factors governing control of the processes, and the influence of the processing methods on the final products.

6120, 6121. *ADVANCED FOUNDRY ENGINEERING.* Credit three hours a term. Consecutive terms. Lectures and recitations. Prerequisites, 6113 or 6114. Mr. KYLE.

The metallurgy of cast ferrous and nonferrous metals and the technology of casting production.

6203, 6204. *SMELTING AND REFINING.* Credit three hours a term. Consecutive terms. Lectures. Prerequisites, Chemistry 404 and Engineering 1256, 6501. Mr. GREGG.

Theory of the reactions involved in the reduction and refining of metals, carburi-

zation and decarburization, slag control, furnace-atmosphere generation, and related topics.

6221. *ADVANCED PROCESS METALLURGY.* Credit two hours. Fall term. Lectures and conferences. Prerequisites, 6203 and 6204. Mr. GREGG.

An advanced course covering the production of metals and alloys.

6253, 6254. *UNIT PROCESSES IN METALLURGY.* Credit three hours a term. Consecutive terms. One lecture and one laboratory period each week, with reports. Parallel courses, 6203, 6204. Mr. GREGG.

Experimental study of important processes in metallurgy, including ore dressing, temperature measurements, generation and control of furnace atmospheres, furnace design and performance, smelting and refining operations and electrodeposition.

6311, 6312. *PHYSICAL METALLURGY.* Credit two hours per term. Consecutive terms. Prerequisite, 6811. Messrs. MASON and BURTON.

Detailed discussion of plastic deformation, recrystallization and grain growth, diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment.

6351. *PHYSICAL METALLURGY LABORATORY.* Credit three hours. Fall term. Laboratory periods and conferences. Parallel course, 6311. Messrs. MASON and BURTON.

Experiments to illustrate the important phenomena of physical metallurgy and special techniques for their investigation.

6501. *METALLURGICAL CALCULATIONS.* Credit two hours. Fall term. Lectures and recitations. Prerequisite, 1255. Mr. GREGG.

An introductory course in the application of the principles of chemistry and physics to metallurgical problems, including combustion, heat balances, gas reactions, and furnace charges.

6602. *METALLURGICAL DESIGN.* Credit three hours. Spring term. Lectures and conferences. Prerequisite, 6312. Mr. BURTON.

Metallurgical and mechanical factors governing the selection of metals for various services. Includes analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment.

6701. *PLANT INSPECTION.* Credit one hour. Spring term. Mr. KYLE.

A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report.

6811. *INTRODUCTORY METALLOGRAPHY.* Credit three hours. Spring term. One lecture and two laboratory periods each week. Prerequisites, 1255 or 1222. Messrs. MASON and BURTON.

Microstructures of alloys, as related to composition, thermal history, and physical properties. Preparation of specimens; principles and use of metallographic microscopes.

6953, 6954. *SENIOR PROJECT.* Credit three hours each term. Two terms. Prerequisite, 6254. Messrs. KYLE, MASON, GREGG, and BURTON.

Research on an original problem in metallurgical engineering.

AERONAUTICAL ENGINEERING

UNDERGRADUATE COURSES

7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING.* Credit three hours. Given as required. Prerequisite, engineering mechanics. An intro-

ductory course for students in all branches of engineering. Emphasis on airplane mechanics: aerodynamic forces, airplane performance, airplane stability and control.

GRADUATE COURSES

7101. *MECHANICS OF AIRPLANES.* Credit four hours. Fall term. Prerequisite, engineering mechanics. Physics of the atmosphere; properties of gases. Dimensional analysis. Laws of compressible fluid motion; fluid forces on bodies. Properties of wings in subsonic, transonic and supersonic flight. Airplane and missile performance estimation. Experimental methods. Mr. ROTT.

7102. *MECHANICS OF AIRPLANES.* Credit four hours. Spring term. Prerequisite, 7101. Introduction to particle dynamics; equations of motion of rigid body in space; Eulerian axes. Stick-fixed and stick-free static longitudinal stability; control-surface forces; power effects. Dynamic stability; lateral stability. Controlled motions of airplanes and missiles; operational methods. Experimental methods. Mr. ROTT.

7203. *AERODYNAMICS OF POWER PLANTS.* Credit three hours. Fall term. Prerequisites, 7101, Physics. Thermodynamics; aerothermodynamics; principles of jet propulsion. Rockets; ramjets; aerodynamic design of compressors and turbines; turbojets; turboprop. Heat transmission; aerodynamics of cooling; cooling of reciprocating engines at altitude; heat-exchanger design; cabin conditioning; thermal anti-icing. Mr. ROTT.

7204. *GASDYNAMICS.* Credit four hours. Spring term. Prerequisite, permission of the instructor. One-dimensional steady flow of a perfect gas with heat addition etc., wave-propagation phenomena, method of characteristics for 2-dimensional and axi-symmetric supersonic steady flow and unsteady channel flow. Experimental methods. Mr. KANTROWITZ.

7206. *SPECIAL TOPICS IN PHYSICAL GASDYNAMICS.* Credit two hours. Given as required. Prerequisites, 8121, 8122, or equivalents, and 7204. A study of various gasdynamical problems in which the molecular kinetics plays an important role. Specific topics to be chosen by consultation. Mr. KANTROWITZ.

7301. *THEORETICAL AERODYNAMICS I.* Credit three hours. Six hours a week during the first half of the fall term. Prerequisites, differential equations, intermediate mechanics or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady and nonsteady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively. Mr. SEARS.

7302. *THEORETICAL AERODYNAMICS II.* Credit three hours. Spring term. Prerequisites, 7301, 7303. Wing theory: thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiplane theory, nonstationary wing theory. Corrections for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases. Mr. SEARS.

7303. *THEORETICAL AERODYNAMICS III.* Credit three hours. Six hours a week during the second half of the fall term. Prerequisites, 7204, 7301. The aerodynamics of compressible fluids: equations of motion, small-perturbation theory (subsonics and supersonic); Janzen-Rayleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow. Messrs. KUO and SEARS.

7304. *THEORETICAL AERODYNAMICS IV.* Credit three hours. Spring term. Prerequisite, 7301. The aerodynamics of viscous fluids: the boundary layer,

heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods. Mr. KUO.

7305. *AERODYNAMICS OF COMPRESSIBLE VISCOUS FLUIDS.* Credit two hours. Fall term. Prerequisite, 7304. The theory of boundary layers and heat transfer in compressible fluids. Phenomena of interaction between shock wave and boundary layer. Experimental methods. Mr. KUO.

7401. *AIRPLANE STRUCTURES.* Credit three hours. Fall term. Prerequisite, strength of materials. Stress analysis of typical airplane structures: trusses, frames, wing structures. Torsion. Shear. Use of stress function. Plastic failure. Failure by buckling: stability of thin-walled structures, theory of shells. Mr. RIPARBELLI.

7402. *AIRPLANE STRUCTURES.* Credit three hours. Spring term. Prerequisite, strength of materials. Fatigue: stress concentration, mechanical vibrations. Impact stresses: response to transient loading conditions. Influence of elastic deformations on aerodynamic loads: static divergence. Wing flutter. Mr. RIPARBELLI.

7403. *AIRPLANE DESIGN.* Credit one hour. Fall term. Orientation: the airplane and its components; the philosophy of airplane design; aircraft materials and processes. Messrs. RIPARBELLI and SEARS.

7404. *AIRPLANE DESIGN.* Credit one hour. Spring term. Prerequisite, 7403. Orientation (continued). Messrs. RIPARBELLI and SEARS.

7406. *SPECIAL METHODS OF STRUCTURAL ANALYSIS.* Credit two hours. Prerequisites, 7401 and 7402. Problems in impact stress distribution. Aero-elastic problems. Wing flutter with two and three degrees of freedom. Mr. RIPARBELLI.

7405. *AERO-ELASTIC PROBLEMS.* Credit three hours. Prerequisites, 7101, 7102. Flutter, divergences, and aileron reversal; control surface vibration at high speeds. Aero-elastic properties of swept-back wings.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING.* (Credit to be arranged.) Prerequisites, admission to the Graduate School of Aeronautical Engineering and approval of the Director. Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM.* Credit one hour. Prerequisite, admission to the Graduate School of Aeronautical Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and visiting scientists on topics of interest in aeronautical science, especially in connection with new research.

7902. *ADVANCED SEMINAR IN AERONAUTICS.* Credit two hours. Prerequisite, approval of the Director. Same as 7901 but devoted to topics of advanced scientific interest.

ENGINEERING PHYSICS

8051 and 8052. *PROJECT.* Terms 9 and 10. Credit three hours each term. Fall and spring terms respectively. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS.* Either term. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121. *CLASSICAL THERMODYNAMICS.* Credit three hours. Fall term. Three recitations a week. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to the kinetic theory of gases and brief introduction to statistical mechanics. Application to physical and engineering problems.

8122. *CLASSICAL THERMODYNAMICS.* Credit three hours. Spring term. Three recitations a week. Continuation of 8121.

8512. *ELECTRON MICROSCOPY.* Credit three hours. Spring term. Prerequisite, consent of the instructor. Lectures, M W F 10. Laboratory hours to be arranged. Mr. SIEGEL.

Basic electron optics, image formation and interpretation, construction and operation of the electron microscope in physics, chemistry, and biology.

8517. *ELECTRON OPTICS AND ITS APPLICATIONS.* Credit three hours. Fall term. Prerequisites, Physics 225 (Physics 215 advised but not required). M W F 11. Mr. SIEGEL.

Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, applications including cathode ray tube, electron microscope, beta ray spectrometer, mass spectrometer.

GENERAL COURSES OF INSTRUCTION

Described in this section are certain courses prescribed for students in engineering, given in the College of Arts and Sciences, the College of Architecture, or other divisions of the University as indicated below.

MILITARY SCIENCE

The University requirement in military science (see p. 13 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied:

(a) by four terms of work in the Department of Military Science and Tactics (Military Science 1, 2 and one of the following pairs: 23,24; 33, 34; 43, 44; 53, 54; or Military Science 61, 62, 63, 64);

(b) by four terms of work in the Department of Air Science and Tactics (Air Science 1, 2, 3, 4);

(c) by four terms of work in the Department of Naval Science while registered either as a regular student or as a contract student in the Naval ROTC (Naval Science 101, 102, 201, 202).

Students who have been enrolled in the armed services are exempted from the requirement in military science. A student who is enrolled in the Organized Naval Reserve Program may postpone the military science requirement while he is so enrolled, and the completion of two calendar years of work in the Program shall satisfy the requirement. Any student registered in the Big Red Band may postpone the military science requirement for the term in which he is so registered, and any student who satisfactorily completes a term of work in the Big Red Band shall be deemed to have satisfied one term of the University military science requirement.

Advanced courses of two years in military and air science and tactics are elective and may qualify students for appointments as Second Lieutenants in the Regular Army or Air Force, the Officers Reserve Corps, U.S. Army, or the U.S. Air Force Reserve.

The Department of Naval Science offers a four-year course of training which may qualify students for appointments as Ensigns in the Regular Navy or Naval

Reserve or as Second Lieutenants in the Marine Corps or Marine Corps Reserve.

Academic credit of three hours a term may be earned in the advanced courses in military and air science and tactics. This credit may be applied toward any of the free electives offered in the curricula of the College of Engineering. Students who complete the four-year course in naval science are given University credit for twenty-four hours of college work. At present, net credit toward degree requirements of the various schools of the College of Engineering is as follows, provided the entire course in naval science is completed: School of Mechanical Engineering, 9 hours; School of Electrical Engineering, 12 hours; School of Chemical and Metallurgical Engineering, 9 hours; School of Civil Engineering, 7 hours; Department of Engineering Physics, 6 hours.

Further details concerning the courses offered in military science may be obtained in the *Announcement of the Independent Divisions and Departments.*

PHYSICAL TRAINING

The University requirement in physical training (see p. 13 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied by four terms of work in the Department of Physical Education. For this purpose Physical Education 1, 2, 3, and 4 are available to men, and Physical Education 51, 52, 53, and 54, to women.

Additional courses in physical education are described in the *Announcement of the Independent Divisions and Departments.*

ARCHITECTURE

REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

Instruction is given by Messrs. MACKESEY, CLARKE, DETWEILER, EDMONDSON, and HOOVER.

700. *HISTORY OF CITY PLANNING.* Fall term. Credit three hours. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned readings, and examinations.

710. *PRINCIPLES OF CITY AND REGIONAL PLANNING.* Fall term. Credit three hours. Open to graduates and upperclassmen. A review of the basic influences in the development of cities. A general view of the theory and accepted practice of city and regional planning, including a study of the social, economic, and legal phases. Lectures, assigned readings, and examinations.

711. *CITY PLANNING PRACTICE.* Spring term. Credit three hours. Prerequisite, Course 710. The procedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned readings, reports.

713. *HOUSING.* Fall term. Credit two hours. Registration limited. Prerequisite, Course 710. An introduction to the theory and standards of housing practice through analysis and comparison of various existing examples, considering the social, economic, and technical sides of the work. Lectures, assigned readings, and reports.

717. *ZONING PRINCIPLES AND PRACTICE.* Spring term. Credit two hours. Prerequisite, Course 710. Technical and legal aspects of drafting and administering zoning regulations.

CHEMISTRY

101-102. *GENERAL CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 101 is prerequisite to Chemistry 102. A terminal course for those students who do not intend to take more chemistry. Will not serve as prerequisite for more advanced courses in chemistry. Open to those who have had or have not had secondary school chemistry. Lectures M F 10 or 11. Laboratory, M T W Th or F 8-10:30, 10:30-1, or 2-4:30, or S 8-10:30. Conference, one hour a week, to be arranged. Mr. HUNT, Mr. OSTERHELD, and assistants.

Emphasis on the more important chemical principles and facts, on the scientific method, and on the relation of chemistry to the other fields of knowledge and to everyday life.

105-106. *GENERAL CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had secondary school chemistry. May be elected by students who do not intend to take more chemistry. Lectures, T Th 9, 10, or 12. Laboratory, M W or F 8-10:30, 10:30-1, or M T W Th or F 2-4:30, or S 8-10:30. Conference, one hour a week, to be arranged. Mr. SIENKO and assistants.

The important chemical principles and facts will be covered, with considerable attention given to the quantitative aspects and to the technics which are important for further work in chemistry.

111-112. *INTRODUCTORY INORGANIC CHEMISTRY.* Credit, three hours each term. Throughout the year. Chemistry 111 is prerequisite to Chemistry 112. Chemistry 115 must be taken with Chemistry 111, except by consent of the instructor. Open to those students who have offered high school chemistry for entrance. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. Lectures, fall term, M W F 8; spring term, W F 8. Mr. LAUBENGAYER and Mr. SIENKO.

115-116. *INTRODUCTORY CHEMISTRY LABORATORY.* Credit three hours each term. Two laboratory periods and one recitation period each week. A study of the application of the principles of chemistry; in Course 116, the work includes the study of the detection of the common anions and cations. Mr. LAUBENGAYER, Mr. BONNER, and Mr. SCHERAGA.

220. *INTRODUCTORY QUANTITATIVE ANALYSIS.* Credit three hours. Either term. Prerequisite, Chemistry 201 or 212. Chemistry 222 must be taken with Chemistry 220. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. Lectures, M W 10. Recitation, one hour a week, to be arranged. Mr. NICHOLS, Mr. SCHERAGA, and assistants.

A study of the fundamental principles of gravimetric and volumetric analysis with practice in stoichiometry.

222. *INTRODUCTORY QUANTITATIVE LABORATORY.* Credit three hours. Either term. Prerequisite, Chemistry 201 or 212. Must be taken with Chemistry 220. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. Laboratory, F 1-4:30 and S 9-12:30 (either term) or T Th 9-12:30 (fall term only). Mr. NICHOLS, Mr. SCHERAGA, and assistants.

Laboratory practice in the preparation and standardization of various volumetric solutions and the analysis of a variety of substances by volumetric and gravimetric methods.

301. *INTRODUCTION TO ORGANIC CHEMISTRY.* Credit two hours. Either term. Prerequisite, Chemistry 105-106. For students in engineering. Lectures, W F 9. Mr. BLOMQUIST.

A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307-308. *INTRODUCTORY ORGANIC CHEMISTRY.* Credit three hours a term. Throughout the year. Prerequisite, Chemistry 201 or 212. Chemistry 215 or 220 and 222 is desirable but not required. Chemistry 307 is prerequisite to Chemistry 308. Chemistry 311 must be taken with Chemistry 307. Required of candidates for the degree of B.Ch.E. and A.B. with a major in chemistry, and recommended for premedical students who desire the longer course. Lectures, M W F 9. Mr. JOHNSON.

A study of the more important compounds of carbon, their occurrence, methods of preparation, relations, and uses.

311. *INTRODUCTORY ORGANIC LABORATORY.* Credit three hours. Fall term. Must be taken with Chemistry 307. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry, and recommended for premedical students who desire the longer course. (See Chemistry 303 and 305.) Laboratory, T Th 9-12:30, T Th 1-4:30, or F 1-4:30 and S 9-12:30. Mr. DeTAR and assistants.

The student prepares typical compounds of carbon and familiarizes himself with their properties, reactions, and relations.

312. *INTERMEDIATE ORGANIC LABORATORY.* Credit three hours. Spring term. Prerequisite, Chemistry 311, parallel course Chemistry 308. Required of candidates for the degree of B.Ch.E., and recommended for candidates for the degree of A.B. with a major in chemistry and premedical students who desire the longer course. (See Chemistry 303 and 305.) Laboratory, T Th 9-12:30, T Th 1-4:30, or F 1-4:30 and S 9-12:30. Mr. DeTAR, Mr. MILLER, and assistants.

A continuation of Chemistry 311.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Credit two hours. Either term. Prerequisite, Chemistry 105-106. Prerequisite or parallel courses: Mathematics 163 or 173 and Physics 117. For students in engineering. Lectures, W F 12. Mr. MUSCHLITZ.

A brief survey of physical chemistry with emphasis on topics of interest to students in engineering.

403-404. *INTRODUCTORY PHYSICAL CHEMISTRY.* Credit three hours a term. Throughout the year. Prerequisite, Chemistry 215 or 220 and 222, 307-308, Mathematics 161-162-163, and Physics 107 and 108 (or their substantial equivalent). Chemistry 403 is prerequisite to 404. Required of candidates for the degree of B.Ch.E. Lectures, M W F 9.

A systematic presentation of the principles of physical chemistry. The topics include the properties of gases, liquids, and solids; physical and chemical equilibrium in homogeneous and heterogeneous systems; the mass law, theorem of Le Chatelier, and the phase rule; thermochemistry and elementary thermodynamics; the theory of solutions; ionic equilibria; chemical kinetics; problems in physical chemistry.

411-412. *INTRODUCTORY PHYSICAL CHEMISTRY.* Credit three hours a term. Throughout the year. Prerequisite or parallel course, Chemistry 403-404, or 407-408. Students may register for either term separately. Enrollment may be limited. Laboratory, M T or Th F 2-4:30. Mr. HOARD, Mr. MUSCHLITZ, and assistants.

Qualitative and quantitative experiments illustrating the principles of physical chemistry, and practice in performing typical physicochemical measurements.

ECONOMICS

107. *INTRODUCTION TO ECONOMICS.* Credit three hours. Either term. Hours to be arranged. For students in engineering. Mr. MORSE and assistants.

An introduction to the more essential economic features of contemporary American society.

203. *MONEY, CURRENCY, AND BANKING.* Credit three hours. Fall term. Prerequisite, Economics 101 or 106. M W F 11. Mr. REED.

A study of our currency system and banking processes for the primary purpose of training the student to determine the influence of monetary factors in economic problems.

ENGLISH

111-112. *INTRODUCTORY COURSE IN READING AND WRITING.* Throughout the year. Credit three hours a term. Open to freshmen, English 111 is prerequisite to 112. M W F 8, 9, 10, 11, 12, 2; T Th S 8, 9, 10, 11, 12. Mr. SALE, Mr. CRONKHITE, and others.

The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others.

ENGLISH FOR FOREIGNERS.

The following two courses are offered by the Division of Modern Languages. Foreign students should consult a member of that division in Morrill Hall 108.

102. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six hours. Prerequisite, placement by the instructor. Hours to be arranged.

211. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six hours. Prerequisite, a satisfactory proficiency examination. Hours to be arranged.

GEOLOGY

113. *ENGINEERING GEOLOGY.* Credit three hours only. Either term. Students who have had Geology 101-102 or 115 may take 113 for one hour credit. Lectures, M W 11. Laboratory, M W or T Th 2-4:30. Mr. ANDERSON.

The purpose of the course is to provide a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions.

712. *METALLURGICAL RAW MATERIALS.* Credit three hours. Fall term. For second year students in metallurgical engineering. Mr. ANDERSON. Lectures, M W F 10.

The source, occurrence, associations, distribution, and economic aspects of the commercially important ore, refractory, and fluxing materials that enter metallurgical operations.

HISTORY

165-166. *SCIENCE IN WESTERN CIVILIZATION.* Credit three hours a term. Throughout the year. A survey of the development of science in its relation to European and American civilization. Primarily for engineers and science majors, but open to other qualified upperclassmen. M W F 11. Mr. GUERLAC.

INDUSTRIAL AND LABOR RELATIONS

293. *SURVEY OF INDUSTRIAL AND LABOR RELATIONS.* Credit three hours. Either term.

A survey for students in other divisions of the University. The course will include an analysis of the major problems in industrial and labor relations: labor union history, organization, and operation; labor market analysis and employment practices; industrial and labor legislation and social security; personnel management and human relations in industry; collective bargaining; mediation and arbitration; the rights and responsibilities of employers and employees; the major governmental agencies concerned with industrial and labor relations.

MATHEMATICS

161, 162, 163. *ANALYTIC GEOMETRY AND CALCULUS.* Credit three hours a term. Three terms; each course is offered each term. Prerequisites, trigonometry and intermediate algebra. Course 161 is prerequisite to 162. Course 162 is prerequisite to 163. Lectures. Fall term: 161, T Th 8, 10, or 12; 162, M W 8; 163, M W 8, 10, or 12. Spring term; 161, M W 8; 162, T Th 8, 10, or 12; 163, M W 8. One recitation a week to be arranged.

Primarily for students in the College of Engineering. Students taking Physics 107 who have not had analytic geometry or calculus should take Mathematics 161 concurrently with Physics 107.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit three hours. Prerequisite, Mathematics 163. Fall term, T Th S 8, 9. Spring term, M W F 12, 2.

Solution of ordinary differential equations by analytic and numerical methods.

607. *APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS.* Credit three hours. Spring term. Prerequisite, Mathematics 163. Times to be announced.

Complex numbers, determinants, Fourier series, solution of algebraic and transcendental equations, vector algebra, theory of errors, and dimensional analysis.

611-612. *HIGHER CALCULUS.* Credit three hours a term. Throughout the year. Prerequisite, Mathematics 201. First term prerequisite to second. T Th S 10, M W F 8.

Primarily for undergraduates. Partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, calculus of variations, Laplace transforms. Emphasis is placed on a wide range of formal applications of the calculus, rather than on the logical development. The second term will be accepted as prerequisite to complex variables.

621-622. *MATHEMATICAL METHODS IN PHYSICS.* Credit five hours a term. Throughout the year. Prerequisites, Mathematics 201 and at least two years of general physics. First term prerequisite to second. M T W Th F 12. Mr. KAC.

For graduate students and qualified undergraduates. Lectures and problem work designed to give the students a working knowledge of the principal mathematical methods used in advanced physics.

PHYSICS

Note: Physics 115, 116, 117 and 118 form a sequence in a two-year continuous course in general physics required of all students of engineering who are candidates for the degree of B.Ch.E., B.C.E., B.E.E., B.Eng.Phys., and B.M.E. Demonstrations, theory, experiments, and problem drill. One lecture, two recitations, and one laboratory period a week, as assigned.

115. *MECHANICS.* Fall term. Credit three hours. Prerequisite, calculus or simultaneous registration in Mathematics 161. Entrance physics is desirable but not required. Lecture, Th 9 or 11. Recitations, M F 9. Laboratory, M 2-4:30. Mr. GRANTHAM, Mr. NEWHALL, and assistants.

Kinetics, statics, elasticity, liquids, and mechanics of gases. The laboratory work consists of measurements related to the above topics.

116. *HEAT, SOUND, AND GEOMETRICAL OPTICS.* Spring term. Credit three hours. Prerequisites, Physics 115, calculus, or simultaneous registration in Mathematics 162. Lecture, Th 9 or 11. Recitations, M F 9. Laboratory, M 2-4:30. Mr. GRANTHAM, Mr. NEWHALL, and assistants.

Temperature, calorimetry, change of state, heat transfer, thermal properties of matter, elementary thermodynamics, wave motion, vibrating bodies, acoustical phenomena, geometrical optics, reflection, refraction, mirrors, and lenses. The laboratory work consists of measurements related to the above topics.

117. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisites, Physics 115, 116, calculus, or simultaneous registration in Mathematics 163. Lecture, T 8 or 11. Recitations, T Th 10. Laboratory, M 2-4:30. Mr. TOMBOULIAN, Mr. NEWHALL, and assistants.

Introductory study of the fundamental laws of electric and magnetic fields and their applications to elementary circuit problems. Electrostatic fields and potential; steady currents, induced emfs, inductance, dielectrics, capacitance, and simple transients. The laboratory work consists of basic measurements in direct current circuits.

118. *PHYSICAL OPTICS AND ATOMIC PHYSICS.* Spring term. Credit three hours. Prerequisite, Physics 117. Lecture, T 8 or 11. Recitations, T Th 10. Laboratory, M 2-4:30. Mr. TOMBOULIAN, Mr. NEWHALL, and assistants.

Properties of electromagnetic waves and their application to optical phenomena: interference, diffraction, and polarization. Selected topics in atomic and nuclear physics: spectra, electron emission, processes, radioactivity, and nuclear reactions. The laboratory work consists of basic experiments in physical electronics and physical optics.

208. *PHYSICAL MECHANICS AND PROPERTIES OF MATTER.* Spring term. Credit three hours. Prerequisites, Physics 115 and Mathematics 161 and 162. Primarily for candidates for the degree of Bachelor of Engineering Physics. M W F 11. Mr. HARTMAN.

Elements of kinematics; Newton's law; conservation laws; D'Alembert's principle; application to selected problems; hydrostatics; elementary fluid dynamics; viscosity; surface tension.

210. *ADVANCED LABORATORY.* Either term. Credit three hours a term. Prerequisites, Physics 205 and 206 or the equivalent. Laboratory, T W or Th F 1:40-4:30. Messrs. PARRATT, CORSON, CUYKENDALL, GREISEN, HARTMAN, McDANIEL, SILVERMAN, and WOODWARD.

About forty different experiments are available among the subjects of mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat, X-rays, crystal structure, solid state, cosmic rays, and nuclear physics. During the term the student is expected to perform five to ten experiments, selected to meet his individual needs. Stress is laid on independent work on the part of the student. Required for physics majors.

214. *ATOM, NUCLEAR, AND ELECTRON PHYSICS.* Spring term. Credit three hours. Two lectures and one recitation. Prerequisites, Physics 118 and Mathematics 607 or the equivalents. Primarily for students in electrical engineering. M W F 10. Mr. SPROULL.

Elements of nuclear and atomic structure, fundamentals of quantum theory, basic kinetic theory of atoms and electrons; electronic processes with special reference to the electrical properties of metals, semiconductors, and insulators and general electron emission processes; elements of nuclear processes.

225. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Pre-

requisite, Physics 117 or 204. Lectures, T Th S 9, and an optional problem period to be arranged. Mr. CORSON.

Electrostatics and electromagnetic fields, polarization of dielectrics and magnetic media, displacement current, plane electromagnetic waves, the Poynting vector.

242. *ANALYTICAL MECHANICS.* Spring term. Credit three hours. Prerequisites, Physics 203 or 208 and Mathematics 201, or their equivalents. T Th S 9. Mr. WOODWARD.

Analytical mechanics of material particles, systems of particles and rigid bodies; planetary motion, stability of orbits; collisions; Euler's equations, gyroscopic motion; Lagrange's equations.

243. *ATOMIC AND MOLECULAR PHYSICS.* Fall term. Credit three hours. Prerequisite, Physics 225, or consent of the instructor. M W F 10. Mr. DEWIRE.

The fundamental particles; statistical physics; the concepts of quantum mechanics; atomic structure and spectra; the periodic table; molecular structure and the chemical bond.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring term. Credit three hours. Prerequisite, Physics 243. M W F 9. Mr. SACK.

Lattice structure; specific heat; lattice energy; elastic properties; electric conduction; thermoelectric effects; contact potential; barrier effect; lattice defects; dielectric, magnetic and optical properties.

258. *MECHANICS OF CONTINUA.* Spring term. Credit three hours. Prerequisite, partial differential equations or consent of the instructor. Hours to be arranged. Mr. SACK.

Equations of state for gases, liquids, solids. Stress-strain relations for continuous media and equations of motion. Special topics in statics of elastic media. Waves and oscillations in continuous media. Topics in flow, and nonlinear phenomena in gases and fluids.

475. *THEORETICAL MECHANICS.* Fall term. Credit three hours. Prerequisite, Physics 242 or its equivalent. T Th S 11. Mr. SALPETER.

090. *SPECIAL GRADUATE LABORATORY WORK.* Either term. One to three credit hours a term. Prerequisite, consent of instructor. Hours to be arranged. Any member of the STAFF.

This work is often arranged and carried out with the facilities and staff of Course 380.

PSYCHOLOGY

101. *INTRODUCTION TO PSYCHOLOGY.* Credit three hours. Either term. Open to freshmen. Fall term: lectures, T Th 9; recitation, M 9, 10, 11, F 12, S 9, or 10; lectures, T Th 11; recitation, Th 2, F 10, 12, 2, S 9 or 10; lectures, W F 10; recitation, M 10, 11, 12, T 12, 3 or S 11; or lectures, W F 11; recitation, M 9, 10, 2, T 12, 2, or S 11. Spring term: lectures, T Th 9; recitation, M 10, F 9, 12, 2, S 10 or 11; or lectures, W F 10; recitation, M 9, 2, T 10, 11, S 10 or 11. The STAFF.

An introduction to the scientific study of behavior and experience, covering such topics as perception, motivation, emotion, learning, the higher thought processes, personality and individual differences. This course is prerequisite to further work in the Department.

PUBLIC SPEAKING

101. *PUBLIC SPEAKING.* Credit three hours. Either term. Not open to freshmen or to students who have taken Speech and Drama 103 or 105. M W F 8, 9,

10, 11, or 12; T Th S 8, 9, 10, or 11. Messrs. ANGELL, ARNOLD, SAVEREID, WICHELNS, and assistants.

Practice in speaking on subjects of current interest; methods of preparation and delivery; various types of speech experience, such as exposition, advocacy, reading aloud, discussion, and chairmanship; study of principles and of examples; conferences.

Foreign students and others whose pronunciation of English falls below the normal standard and students with special vocal problems are advised to confer with Mr. THOMAS before registering.